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VOLUME 1 REPORT

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PREFACE

This report is one of several emanating from the Shipbuilding Technology Transfer Program performed by Livingston Shipbuilding Company under a cost sharing contract with the U.S. Maritime Administration.

The material contained herein was developed from the study of the Engineering and Design programs and systems presently in operation in the shipyards of Ishikawajima-Harima Heavy Industries (IHI) of Japan. Information for this study was derived from source documentation supplied by IHI, information obtained directly from IHI consulting personnel assigned on-site at Livingston, and from personal observations by two teams of Livingston personnel of actual operations at various IHI shipyards in Japan.

In order to place this study in context within the overall Technology Transfer Program, a brief overview of the program and its organization is provided in the following paragraphs:

THE TECHNOLOGY TRANSFER PROGRAM (TTP)

The U.S. shipbuilding industry is well aware of the significant shipbuilding cost differences between the Japanese and ourselves. Many reasons have been offered to explain this differential and whether the reasons are valid or not, the fact remains that Japanese yards are consistently able to offer ships at a price of one-half to two-thirds below U.S. prices.

Seeing this tremendous difference first hand in their own estimate of a bulk carrier slightly modified from the IHI Future 32 class design, Livingston management determined to not only find out why this was

true but to also attempt to determine precise differences between IHI and Livingston engineering and design practices; production planning and control methods; facilities, production processes, methods and techniques; quality assurance methods; and personnel organization, operations and training. The obvious objective of such studies was to identify, examine and implement the Japanese systems, methods and processes which promised a significant improvement in the Levingston design/production process.

With this objective in mind, and recognizing the potential application of the TTP results to the American shipbuilding industry, Levingston initiated a cost-sharing contract with MarAd to provide documentation and industry seminars to reveal program findings and production improvement results measured during production of the bulkers. Subsequently, Levingston subcontracted with IHI Marine Technology Inc. (an American corporation and a subsidiary of IHI, Japan) specifying the areas to be explored and the number and type of IHI consulting personnel required during the period of re-design and initial construction of the first bulker.

Basically, the program is organized into six major tasks:

1 - Cost Accounting

2 - Engineering and Design

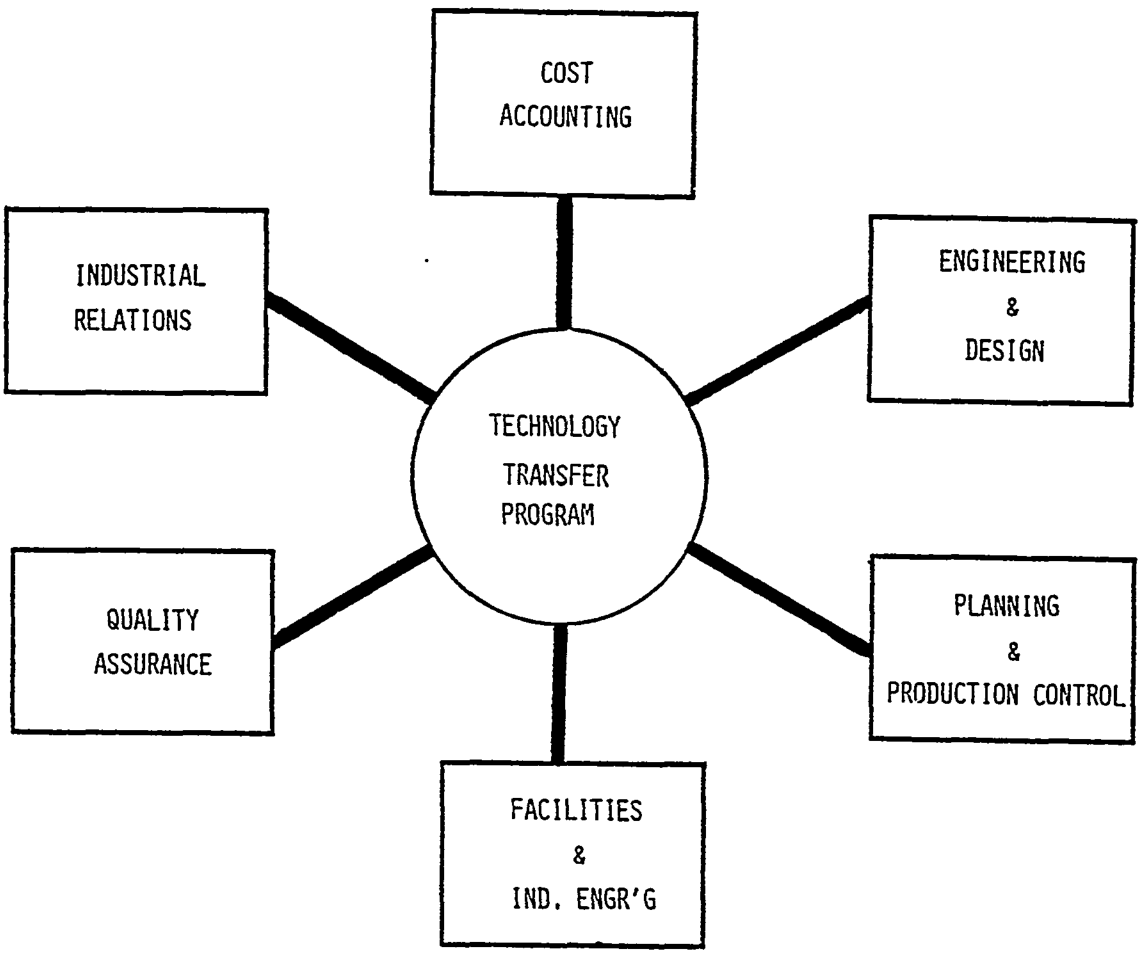
3 - Planning and Production Control

4 - Facilities and Industrial Engineering

5 - Quality Assurance

6 - Industrial Relations

Beneath each of these major tasks is a series of sub-tasks which further delineate discrete areas of investigation and study. Each sub-task area has been planned and scheduled to: 1) study IHI systems, methods and techniques; 2) compare the Levingston and IHI practices; 3) identify improvements to the Levingston systems; 4) implement approved changes; 5) document program findings, changes to the Levingston systems, and the results of those changes; and 6) disseminate program findings and results to industry via MarAd.



SECTION 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

The purpose of this study was to analyze the Japanese (IHI) concept of design engineering and its application in the actual working environment in IHI shipyards. As in the many other areas of study within the Technology Transfer Program (TTP) the objective of the study was to define possible beneficial and cost-saving elements or methodologies which could be instituted in Levingston and in other medium size shipyards in the United States.

In this examination of the IHI design engineering concepts and applications, particular attention is given to the flow of work beginning with the Basic Design through the Functional Design to the Detail Design.

1.2 ORGANIZATION

This report comprises two volumes: I - Findings and Conclusions and II - Appendices. This volume consists of six sections:

- Section 1 - Introduction
- Section 2 - Design Initiation
- Section 3 - Shipyard Design & Engineering
- Section 4 - Computer Aided Design
- Section 5 - Numerical Control Steel Fabrication
- Section 6 - Levingston System and Application of IHI Technology

Sections 2, 3, 4 and 5 comprise an account of the findings and an analysis of the concepts employed and the actual functioning of these concepts in IHI.

Several appendices (source data) are also included as Volume II of this report. These appendices are listed below:

Appendix A - Brief Explanation of IHICS

Appendix B - IHICS - Actual Output Examples

Appendix C - Summary of IHI SHELL

Appendix D - LODACS - Ship Frame Data Processing System

Appendix E - SPECS - Ship’s Preliminary and Exact Calculation System

Appendix F - SPECS - Actual Output Example

Appendix G - CADS - Piping Design System

Appendix H - IHI Report on Computer-Aided Design System

Appendix I - IHI Report on Numerical Control Steel Fabrication

Appendix J - LSCo Study and Comparison of SPADES vs. IHI System

Appendix K - LSCo Sub-task Report - Computer-Aided Design Systems

Appendix L - LSCo Sub-task Report - Numerical Control Steel Fabrication

Appendix M - IHI Working Flow and Scheme for Hull Strucutre Design

Appendix N - Explanation of IHI’s Design Flow (Piping)

Appendix O - Z PLATE - General Purpose Program of Plane Stress Analysis by Finite Element Method, and Its Application

Appendix P - Z VIBRA - Matrix Method of Vibrational Analysis of Framed Structures, and Its Application

SECTION 2

DESIGN INITIATION

2.1 GENERAL

This report describes the overall design and engineering function which is responsible for ship design and the dissemination of design and construction information to Production. This design and engineering activity is accomplished by a "top-down" refinement procedure which begins with a conceptual ship design determined through research and design teams at the IHI Head Office. This conceptual design is refined to become the basic design. Figure 2-1 describes the flow as the conceptual design is transformed from concept to basic guidelines, to functional diagrammatic design and finally to detail design. It is this flow that is described in this report.

2.2 BASIC DESIGN AT THE IHI TOKYO HEAD OFFICE

The basic design group of the IHI Head Office (in Tokyo) is composed of approximately 100 persons primarily involved in creating the design of new vessels to be built at one of the IHI shipyards. Working in conjunction with the Marketing Survey Group, the Initial Development Group, and the Sales and Estimation groups, the basic Design Group develops a conceptual ship design into a basic design package which consists of specifications, ships lines, general arrangement drawings, miship section drawings and naval architectural data and calculations.

The Basic Design Office is organized into three groups according to vessel size and functional responsibilities as illustrated in Figure 2-2. The No. 1 Basic Design Group for small and medium size

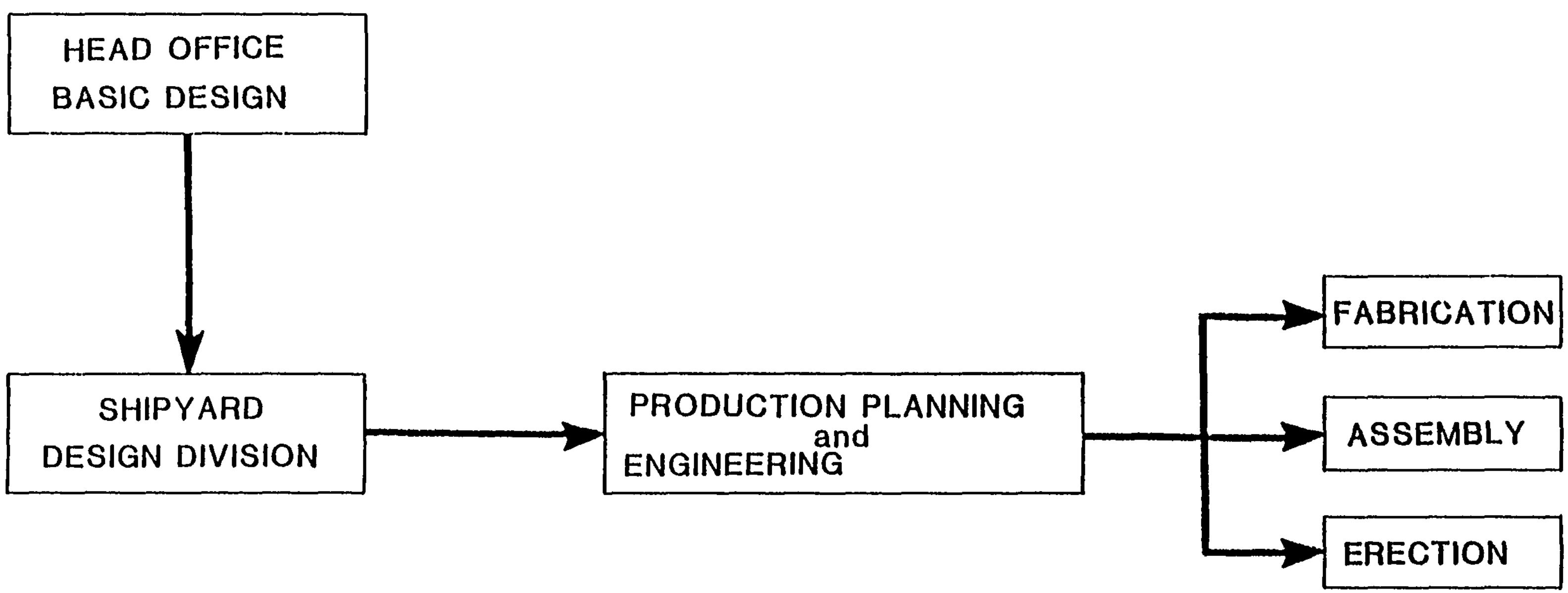


FIGURE 2-1

BASIC FLOW OF DESIGN FOR PRODUCTION

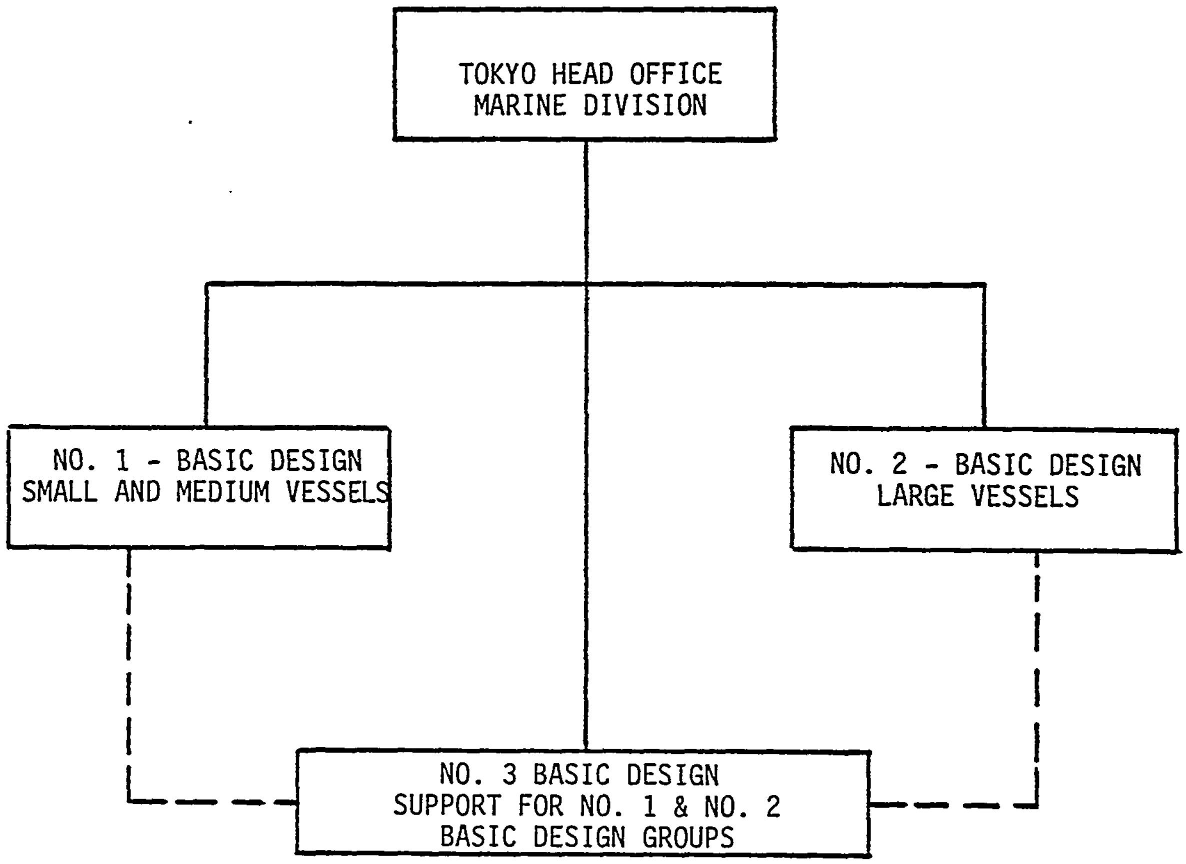


FIGURE 2-2

BASIC DESIGN OFFICE

vessels and the No. 2 Basic Design Group for large vessels are referred to as “think tanks”. The educational level of these groups is high with 85% holding college or university engineering degrees.

In support of these two groups is the No. 3 Basic Design Group which is further divided into four groups: 1) the Administration Group which performs the clerical functions of the department; 2) the Ship’s Form Group which provides the design for the size and shape of the vessel; 3) the Hull Structure Group which determines the structural requirements for the hull; and 4) the Electric Group which provides the basic design for the power systems of the vessel.

When the basic design package contains enough information to allow the ship’s price to be estimated, the package is submitted to the o the ship's owner for contract approval. Instrumental in the preparation of the estimate is the basic material list. This list is in rough quantities but will systematically be updated throughout the design process as more detailed or accurate information becomes available. Material is listed by the following categories: hull, hull outfitting, machinery outfitting and electrical. The outfitting lists are prepared system by system, which facilitates updating isolated changes. Thus, if one system is changed, re-listing involves only the affected system. This list becomes part of the historical record of each vessel design. Because the basic material Iist is made very early, Key Plans from other similar vessels are used extensively for reference.

The basic design package is the basis for the development of the Key Plans for the ship being designed. Computer output is utilized in preparation of the key plans as the drawings are rapidly produced

at l/100th scale. These drawings are not finished at the Head Office but are transferred to a shipyard to be completed. The shipyard is selected by the Head Office on the basis of its capabilities and capacities in relation to ship size and type and in consideration of current work in process and yard backlog.

A preliminary blocking plan, or unit breakdown is also prepared at the Head Office to be finalized at the selected shipyard soon after the basic design package is transmitted.

SECTION 3

SHIPYARD DESIGN & ENGINEERING

3.1 ORGANIZATION

The functional responsibilities of the Shipyard Design Group comprise the following: basic design, key plans, yard plans, and computerization. Preparation of design information according to these major categories begins upon receipt of the basic design package from the Head Office Basic Design Group.

The shipyard's basic design group is responsible for maintaining specifications, customer requirements and general arrangement drawings. This group also provides detail naval architectural data.

The key plan group prepares detail scantling data, schematic diagrams and functional plans, purchase order specifications, lists of materials for procurement, outfitting materials fabrication drawings, and material lists for fabrication drawings.

The yard plan group, or working drawing group, prepares detail fabrication drawings, detail outfitting drawings, material lists for outfitting, pipe piece manufacturing drawings, and material lists for pipe piece manufacturing drawings.

Of the above data, the following-are prepared by computer: list of materials for procurement, material list for outfitting, pipe piece manufacturing drawings, and pipe piece drawing material lists. Input data for other computer-generated data such as material control cards and lists, purchase order cards and sheets, warehousing control sheets and purchasing lists are also prepared by the design groups.

The major functions listed above can all be found in each design group or section of the shipyard design department. Figure 3-1 illustrates the organization of the shipyard design department and Table T3-1 lists the specific functions of each group.

3.2 TYPICAL DESIGN SYSTEM AND FLOW

All shipyard design drawings are made according to the contract, basic drawings, and the manufacturer’s drawings. This is accomplished through cooperation between all sections of the Shipyard Design Department. The basic drawings are finalized and submitted to the ship owner for approval and are subsequently distributed to the various sections of the yard’s design department to become Key Plans and eventually Yard Plans.

The basic design drawings consist of general arrangements, ship’s lines, preliminary machinery arrangement, midship section, specifications, and calculations. These data are expanded to make up the Key Plans which describe the vessel in further detail in each major area (i.e. holds, bow, stern, house). These drawings will then become the basis for the working drawings or Yard Plans.

The IHI Shipyard Design organization functions to provide clear and concise information in support of Production. The basic flow of drawings is illustrated in Figure 3-2. Table T3-2 shows the major items produced by the shipyard design organization.

In the process of completing the design, a major objective of the design department is to facilitate optimum utilization of yard capabilities and facilities. This objective is instrumental in determining the blocking plan, or unit arrangement, which is accomplished from two weeks to one month after the transfer of the basic design.

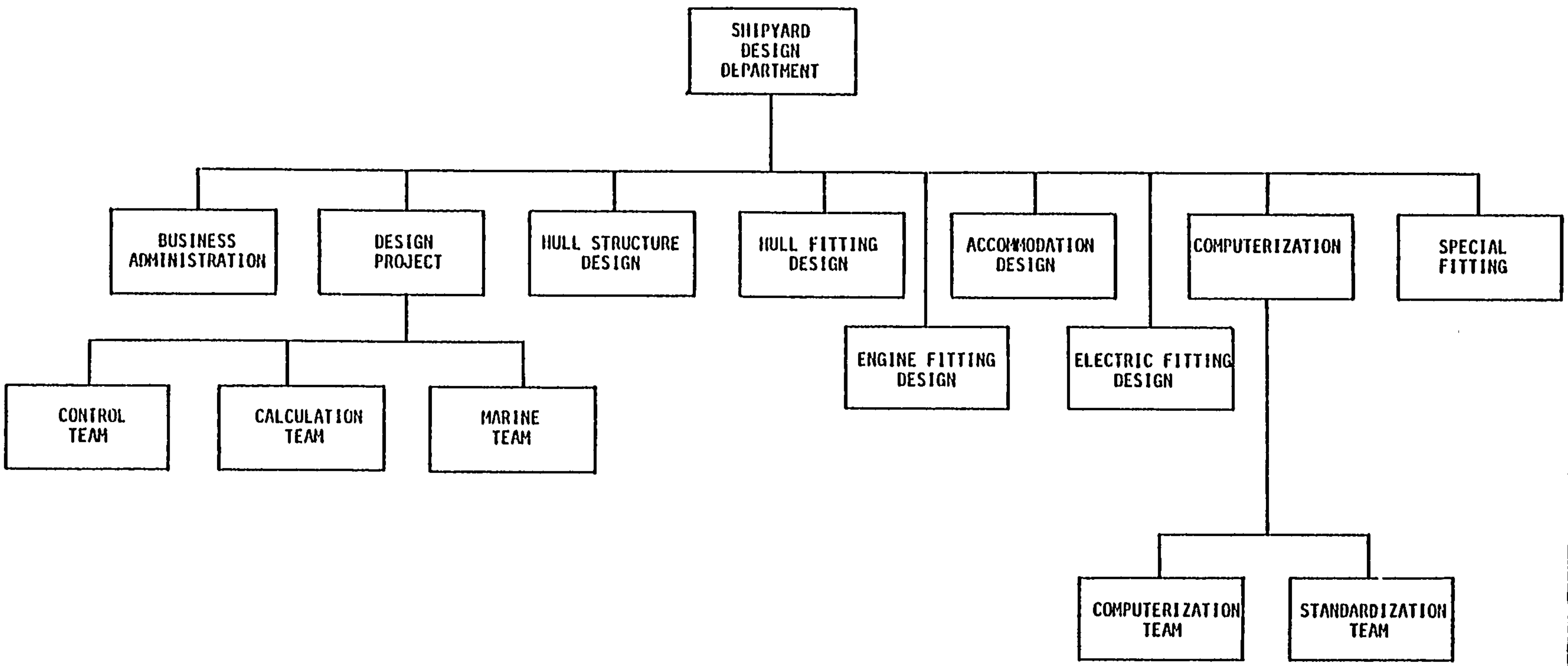


FIGURE 3-1

DESIGN DEPARTMENT ORGANIZATION

TABLE T3-1

MAJOR FUNCTIONS OF SHIPYARD DESIGN DEPARTMENT GROUPS

1. Business Administration Group

   * General service for each design section
   * Drawing schedule
   * Working schedule
   * Estimations

2. Project Design Group

   a. Control Team * Administration of each design group
   b. Calculation Team * Calculation of ship's properties
   * Tonnage measurement
   c. Marine Team * Consultant work and drawing supply for overseas shipyards

3. Hull Structure Design Group

   * Key plans of hull structure
   * Yard plans of hull structure
   * Block (unit) arrangement
   * List of hull structural members including weight and fillet weld length

4. Hull Fitting Design Group

   * Key plans of hull fittings and piping
   * Purchase order specifications for fittings
   * Fitting arrangement plans
   * Production drawings of hull piping and outfitting
   * MLF, MLS

5. Accommodation Design Group

   * Key plans of accommodations quarters
   * Joiner arrangement
   * List of upholsteries and fittings
   * Purchase order specifications
   * Production drawings of accommodations quarters
   * Key plans and yard plans of superstructure

6. Engine Fitting Group

   * Machinery arrangement
   * Piping diagram of engine room
   * Purchase order specification
   * Sea trials plans
   * Production drawings of engine room
   * Funnel fittings
   * Tanks and auxiliary foundations

7. Electric Fitting Design Group

   * Wiring diagram
   * Purchase order specifications
   * Electric fitting arrangement
   * Equipment for lighting and cable installation

8. Computerization Group

   * Systems and programs development
   * Maintenance of programs and manuals
   * Standardization of fittings

9. Special Fitting Design Group

   * Design of cargo gears and hatch covers
   * Design of rampways, stern and bow doors, special racks and carriers, etc.
   * Purchase order specifications
   * Heavy lifts, dredging, etc.

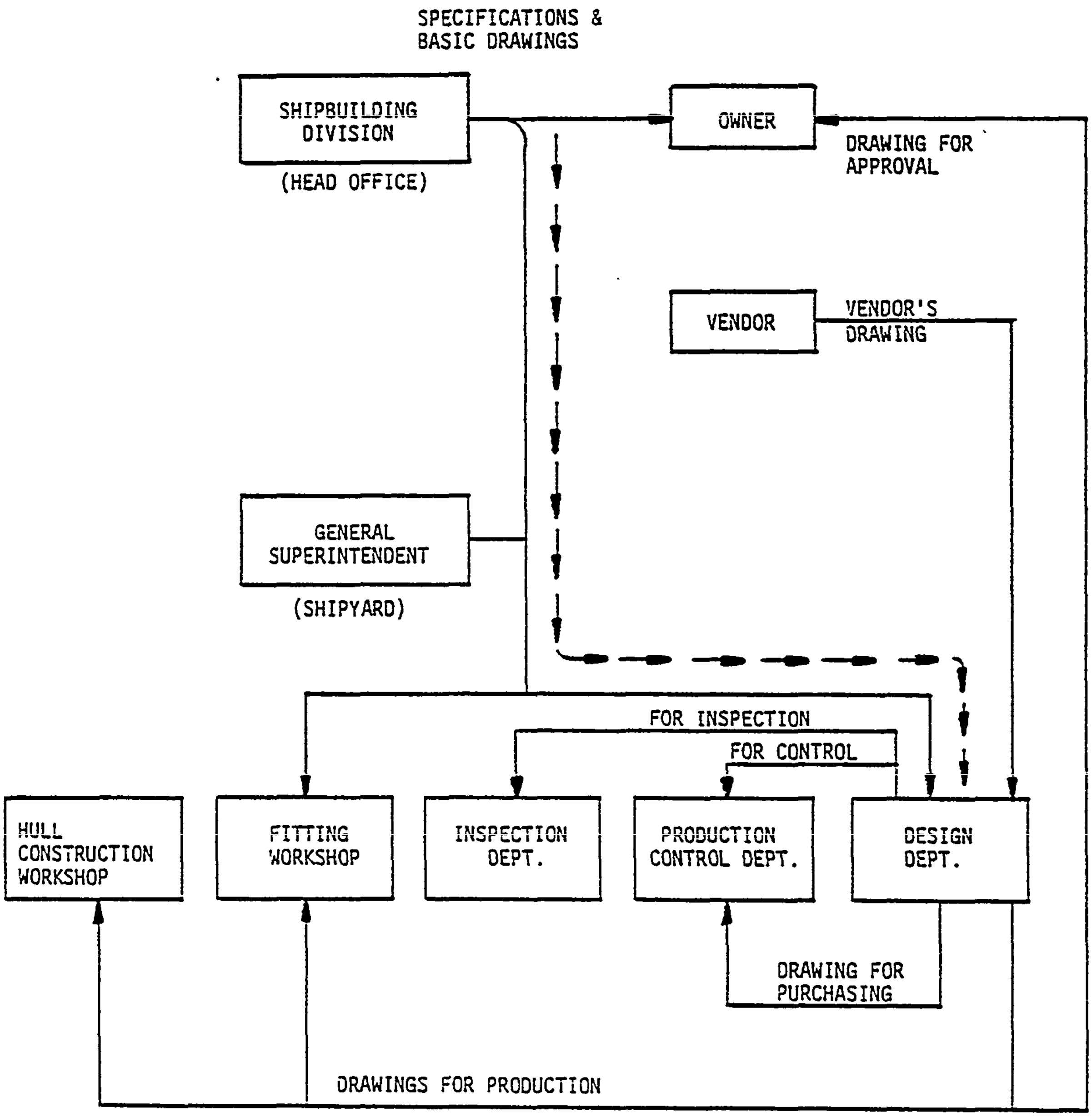


FIGURE 3-2

BASIC FLOW OF DRAWINGS

MAJOR ITEMS PRODUCED BY SHIPYARD DESIGN ORGANIZATION

*** OUTFITTING KEY PLANS**

- Machinery Arrangement
- Joiner Arrangement
- Piping Diagram”
- Purchase Order Specifications (Main Machinery)
- MLS (Long Term Delivery Items)
- MLS (Material List by Systems)

HULL KEY PLANS

- Hull Scantling
- Unit Weight (Approx.) Preliminary Unit Arrangement
- Midship Section & Typical Transverse Bulkhead
- Stern & Rudder
- Main Eng. & Equip. Foundations
- Plan of welding
- Stress & Vibration Research

***OUTFITTING YARD PLANS**

- Compartment Arrangement
- Pallet List
- Composite Drawings
- Manufacturing Drawings (MLP, MLC) Manufacture of Pipe and other Components
- Module Assembly Drawing
- On-Unit Fitting Drawing
- MLF
- Purchase Order Specs (Short Term Delivery Items)
- On-Board Fitting Drawings

HULL YARD PLANS

- Unit Arrangement
- Unit Weights - Exact
- Unit Center of Gravity
- Welding Length
- Working Drawings & Structural Details
- Piece List
- Auxiliary Equipment Foundation Drawings

*Outfitting Design is divided into deck, accommodations, machinery and electric groups.

TABLE T3-2

3.2.1 Development of Key Plans

The key plans and hull calculations are prepared by the key plan teams of the Hull Structural Design Group, the Hull Fitting Design Group and the Accommodation Design Group. The structural design is accomplished using IHI computer programs "Z Plate" and "Z Vibra" (see Appendices). The outputs from these programs are both printed and plotter-drawn and are used for the development of a complete Key Plan package for the hull structure. This set of plans is issued as early as three weeks after the yard receives the unfinished key plans from the Head Office.

A complete set of Key Plans includes the following:

1. Calculation of midship structure
2. Calculations of transverse strength of shell plate
3. Calculations of buckling strength of shell plate
4. Calculations of strength of transverse and longitudinal bulkheads
5. Calculation of plating sheer diagrams
6. Calculation of local vibrations
7. Calculation of scantling beyond midship part
8. Calculation of steel weight of the hull
9. Calculation for main foundations
10. Rudder design
11. Stern frame design
12. Outfitting Key Plans
    a. Piping
    b. Mechanical
    c. Electrical
    d. Accommodations

Standardization and computerization significantly enhance the productivity of the design function. Many drawings are rapidly produced on a drum plotter, thus utilizing the computer data bank of ship's information. The Hull Structure Group prepares the loading information for the data base which in turn produces the shell landing data. This input is normally entered via CRT but may be prepared manually and checked on a graphic display. The plotter is suitable for lines and shell expansion drawings and is also utilized for structural analysis by producing drawings which show structural diagrams and plotted stress locations.

The data are also used by the mold loft which is equipped with remote stations composed of a CRT and three large, automatic flat-bed drafting tables. Through these machines, design information reaches Production in the form of 1/10 scale, highly accurate, shape templates used in the fabrication of hull parts.

3.2.2 Development of Yard Plans

The next step in the shipyard's engineering process is the preparation of Yard Plans or working drawings. All hull structural detail information, block (or unit) arrangement, unit weights, weld lengths, center of gravity of units, piece lists and auxiliary foundation drawings are developed at this time.

The IHI drawing system is structured in such a way that a minimum of re-drawing is necessary. The drawings and material lists are prepared by various sophisticated photographic methods as well as computerized and manual drawing techniques.

The yard plan drawings are made according to the unit arrangement

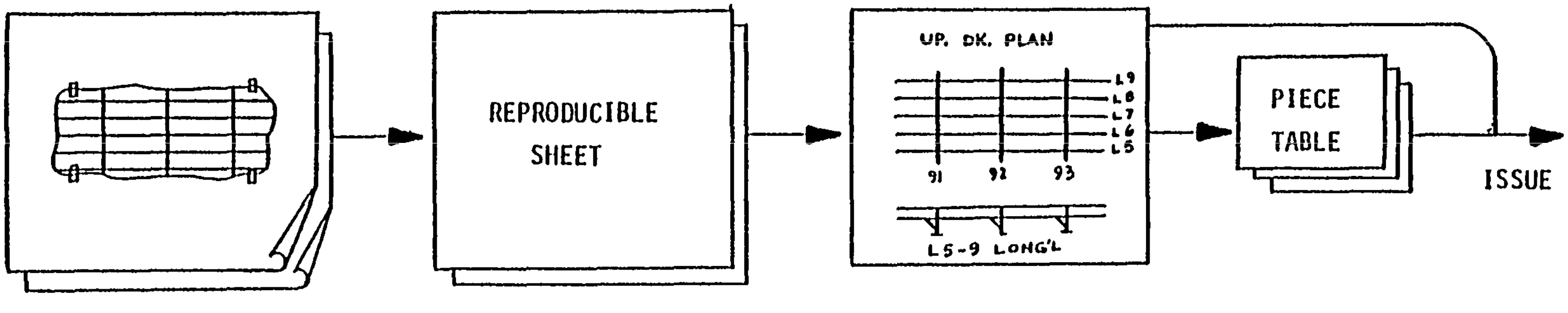
and consist of a title sheet and several sheets comprising the structure and details of an individual unit. These drawings are distributed to the various departments for planning, lofting, construction and outfitting purposes. Figure 3-3 depicts the process flow for preparation of Yard Plans.

In the design office, the Hull Yard Plan is worked closely with the Outfitting Yard Plan to minimize negative effects of design for the many structure penetrations for piping, ventilation, and electrical systems. Discussions and coordination provide the key for making the Yard Plan an effective tool in hull construction.

The issuance of the Yard Plans usually begins at K-3-l/2 (keel lay minus three and one-half months). This allows a month or more before the actual processing of steel begins. Thus, the timely issuance of the Yard Plan is extremely important. Table T3-3 describes the actual contents of the numerous and varied drawings and the list of yard plans that are actually distributed to the worksites.

3.3 HULL CONSTRUCTION ENGINEERING

Shipyard design activities typically accomplish a great deal of the production planning commensuarte wtih the development of the detailed working drawings. However, the principal activities of the design function of the yard are to identify and define the material which is to be procured versus that which is to be manufactured internally. From system diagrams, shell expansion drawings, section drawings, shipyard standards and a series of material lists, design personnel determine the material to be procured including steel, components and consumables. Although there are many innovations in the IHI procurement system, the engineering/procurement interface and



Parts of Key Plans are cut out, arranged and pasted up for reproduction. Key Plans are 1/100 scale.

Reproducible sheet is photographically enlarged to 1/50 scale.

Details, sections and other descriptions are added manually.

Piece tables are made for each unit including piece descriptions, piece weights and unit weight.

FIGURE 3-3

PROCESS FLOW OF YARD PLAN PREPARATION

TABLE T3-3

CONTENTS OF YARD PLANS

1. Principal Material List - the basic list of all materials to be used. By studying this list, the volume of fabrication work can be estimated.

2. Drawing List (MLA) - the kinds of drawings to be prepared by the yard's design department and the dates of completion.

3. Arrangement Drawings - indicate the arrangement of the ship as a whole, as well as the arrangement of the main equipment. These drawings describe the types of fabrication work to be done and serve as the basis for the fitting drawings. The block (or unit) arrangement shows all blocks of the vessel and provides the frame of reference for design and production of each vessel.

4. Body Plan (Hull Construction) - provides details of the hull structure and serves as a basis for the fitting drawings.

5. Diagrams - Indicate the functional systems of all outfitting equipment and serve as a basis for fitting drawings. Some diagrams are used directly in outfitting work as well as for systems performance checking.

6. Practices - contain the items of agreement or rules for actually carrying out the design work as well as fabrication work. They contain detailed instructions not found in the specifications.

7. Manufacturer's Drawings - are drawings of the auxiliary machinery to be fitted on the ship. The drawings are used by sub-contractors in the manufacture of items not made in the yard. They are used as reference material for the installation and operation of equipment.

8. Fitting Drawings - indicate the mounting positions of outfitting equipment and are the main drawings used by the Outfitting Department. Virtually all actual fitting work is done on the basis of these drawings. They are prepared by work stage and work zones.

9. Materials List (MLF) - contains all outfitting materials necessary for advancing the work based on the fitting drawings.

10. Piece Tables - are used when manufacturing pipes and are the basic drawings used at the pipe shop. The pipes in the fitting drawings are picked up one by one and a drawing is prepared for each. These drawings are grouped by MLF units.

the purchasing procedures are relatively similar to those of U.S. yards.

The design for manufacture is the primary function of the yard design division. From the top-level drawings and specifications, the details of the ship are progressively developed to the lowest level necessary for the fabrication of parts and pieces, sub-assembly of individual components (both hull parts and outfitting parts), assembly of hull units and final erection of these units on the ways. Figure 3-4 shows the development and progression of drawings.

Throughout the design development, detail planning and scheduling is performed by a consolidated group of design engineers, planners and production engineers. This planning is part of the design process in that an iterative cycle of design - planning - design occurs at each level of drawing development. On the basis of the top-level design the hull is subdivided into major hull units suitable for handling, outfitting and erecting. Subsequently, each unit is further divided into its detailed parts which are identified on material lists for either procurement or manufacture. Design engineers progressively detail each level of the ship breakdown in drawings of units, sub-assemblies of hull and outfitting components and detail parts and pieces.

As part of the planning/detail design development process, a series of planning documents are developed. Detailed assembly procedures are documented for each unit in Assembly Specification Plans and a series of Working Instruction Plans provide data relevant to: Marking, Cutting and Bending of plates during fabrication; Unit Parts

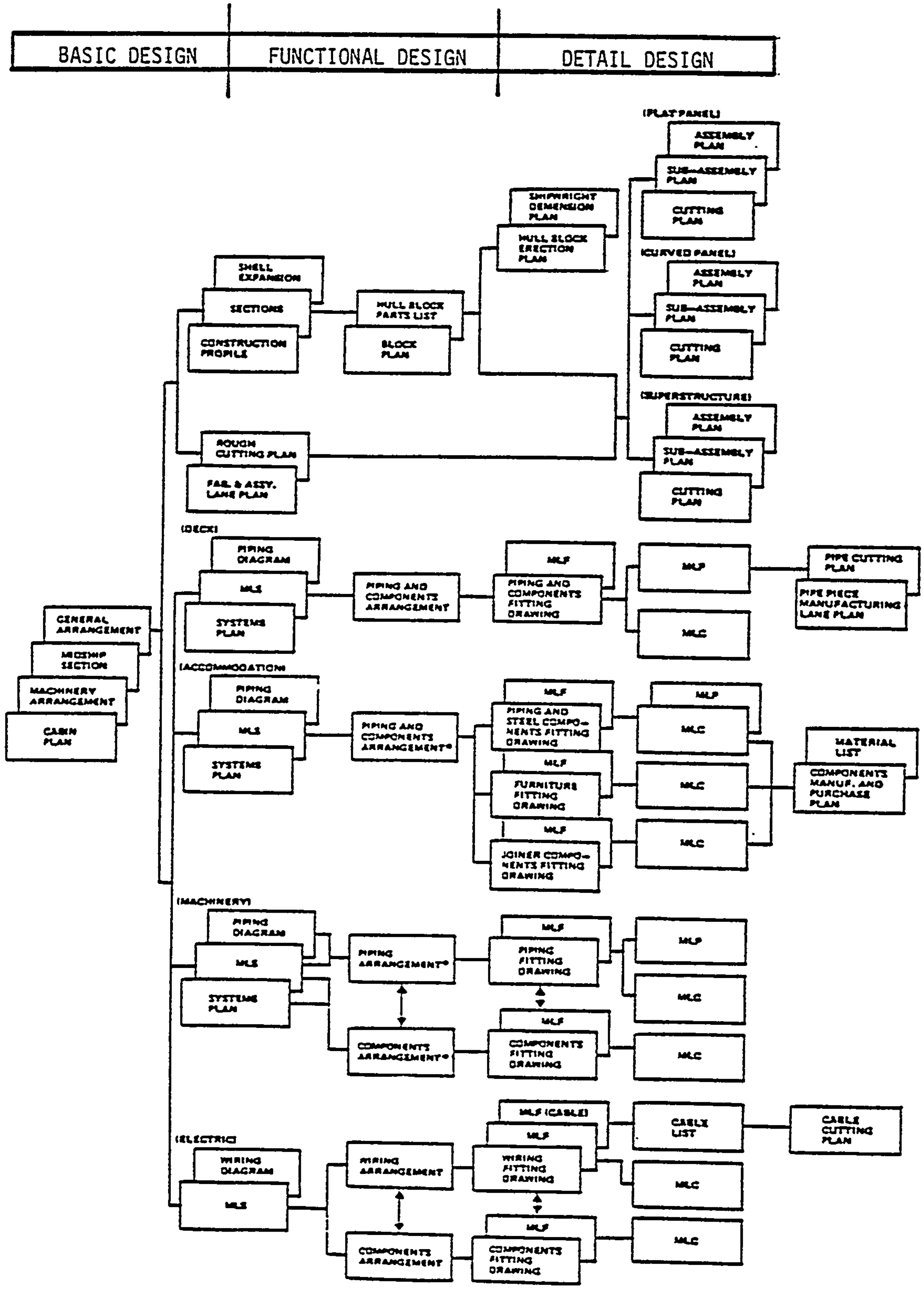


FIGURE 3-4

DESIGN DEVELOPMENT

Lists, Finish Dimension Plans for each unit; Sub-assembly Plans; Assembly Plans; Assembly Jig Size Lists; and Lifting Instruction for each unit. Working Instruction Plans are also prepared for specific elements of the erection process, such as: the Unit Arrangements Plan; Shipwright Dimensions Plan; Support Block Arrangements Plan; Welding Instructions; and a Scaffolding Arrangements Plan.

Simultaneously with the design development and production planning, Accuracy Control Engineers designate the critical dimensions of the procured and manufactured components and units to assure the highest accuracy of the product at each stage of production. This Accuracy Control activity greatly influences the design and the selection of the production processes to be utilized. It also forms the basis for the quality control of each “interim product” (i.e. sub-assembly or hull unit) as it is built up through the fabrication, sub-assembly and assembly cycle. Figure 3-5 depicts the concept of Accuracy Control in IHI. Several Livingston reports referenced herein discuss the application of Accuracy Control.

Throughout this design process Production Planning and Engineering personnel attached to each of the Panel, Hull and Outfitting Workshops, provide appropriate production information and requirements to the designers. The working drawings and plans are carefully prepared to closely match facility and production organization capabilities. The shipyard design division is considered a support organization to production in this activity and is thoroughly oriented toward providing all design and planning information required by the production workshops to enable the best possible flow of precise and accurate material throughout the construction process.

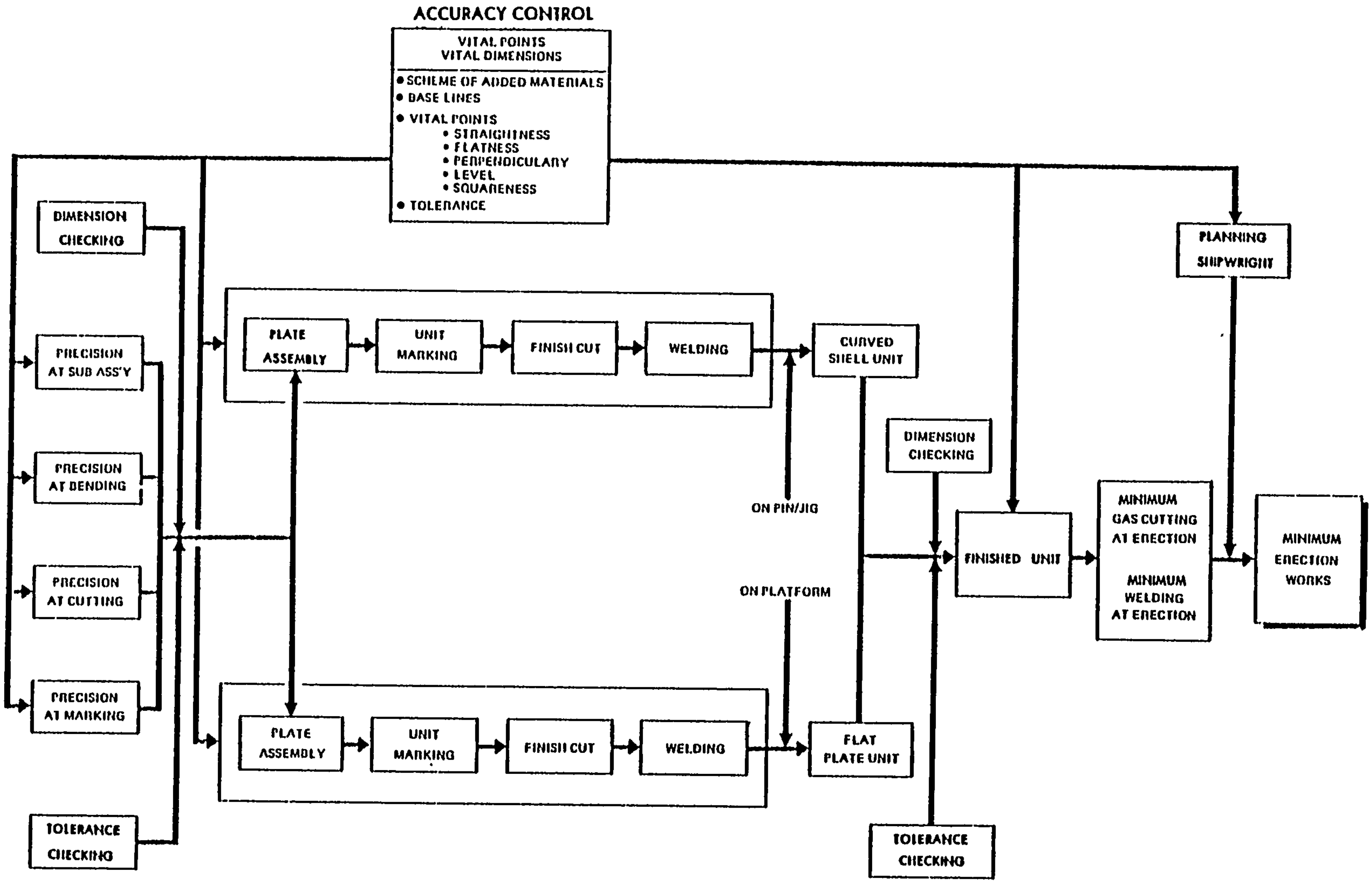


FIGURE 3-5

CONCEPT OF ACCURACY CONTROL IN IHI

3.4 OUTFITTING ENGINEERING

3.4.1 Design and Material Listing

The basic design planning for outfitting occurs during the evolution of the Basic Design into the detail working drawings. Subsequent to receipt of the Basic Design, the shipyard design department, in collaboration with the Fitting Workshop Production Planning and Engineering staff, develops system diagrams for each functional system of the ship. These diagrams do not reflect any sub-division of the ship into hull units. The diagrams do however, define all components required in each functional system. On the basis of these diagrams, a Material List by System (MLS) is compiled. These lists provide an itemization of the bulk and raw materials and system components required for a particular "Material Ordering Zone". Figure 3-6 provides an example of an MLS.

IHI establishes a series of "Zones" for each ship: major zones, which are primarily used for sub-dividing the ship for the purpose of hull construction; Material Ordering Zones, which are used to categorize material for procurement; Outfitting Zones, which designate major areas of outfitting; and, Outfitting Work Zones, which are further sub-divisions of Outfitting Zones into discrete small packages of outfitting work. Figure 3-7 illustrates these different types of zones.

Material Ordering Zones range from four to seven depending on the type of ship. The first four zones are: the cargo hold, the engine room, the main deck, and the house. Electrical outfitting is nearly always considered as a separate zone which makes five basic zones of a ship such as a tanker or bulk carrier. Container ships or combination container/bulk carriers would require additional material zones.

MLS

番船別装置部品表

材料品コード MTL. CODE	品名 DISCRIPTION / 材質、型式、規格、寸法 / 引当指示項目	取付符号 PIECE NO.	コード CODE	単位	数量 NO. (NET) / (GROSS)	重量 W/T (NET)	引出図番	手配区画 SUB ZONE	備考
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403002015	** SUB-TOTAL ** SUB-TOTAL	** **		100 100		10400		34	
403003008	FC S.D.C.GLOBE VALVE FC/BC FN 5050GB	31,30,00 S-222V	A32	1	10 10	140 140		34XH1AP--0 34XH1AP--0	98 18392 2 0800
403003008	** SUB-TOTAL ** SUB-TOTAL	** **		10 10		140		34	
403003009	FC S.D.C.GLOBE VALVE FC/BC FN 5065GB 922348 362902	32,60,00 O-019V	A32	1	10 10	213 213		34X118---0 34X118---0	0800
403003009	** SUB-TOTAL ** SUB-TOTAL	** **		10 10		213		34	
403003010	FC S.D.C.GLOBE VALVE FC/BC FN 5080GB 922367 364901	33,10,00 R-201V	A32	1	10 10	276 276		34XH3AP--0 34XH3AP--0	0800

(2205) 8×12.5' 1.55 (148-111)

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FIGURE 3-6

MATERIAL LIST BY SYSTEM

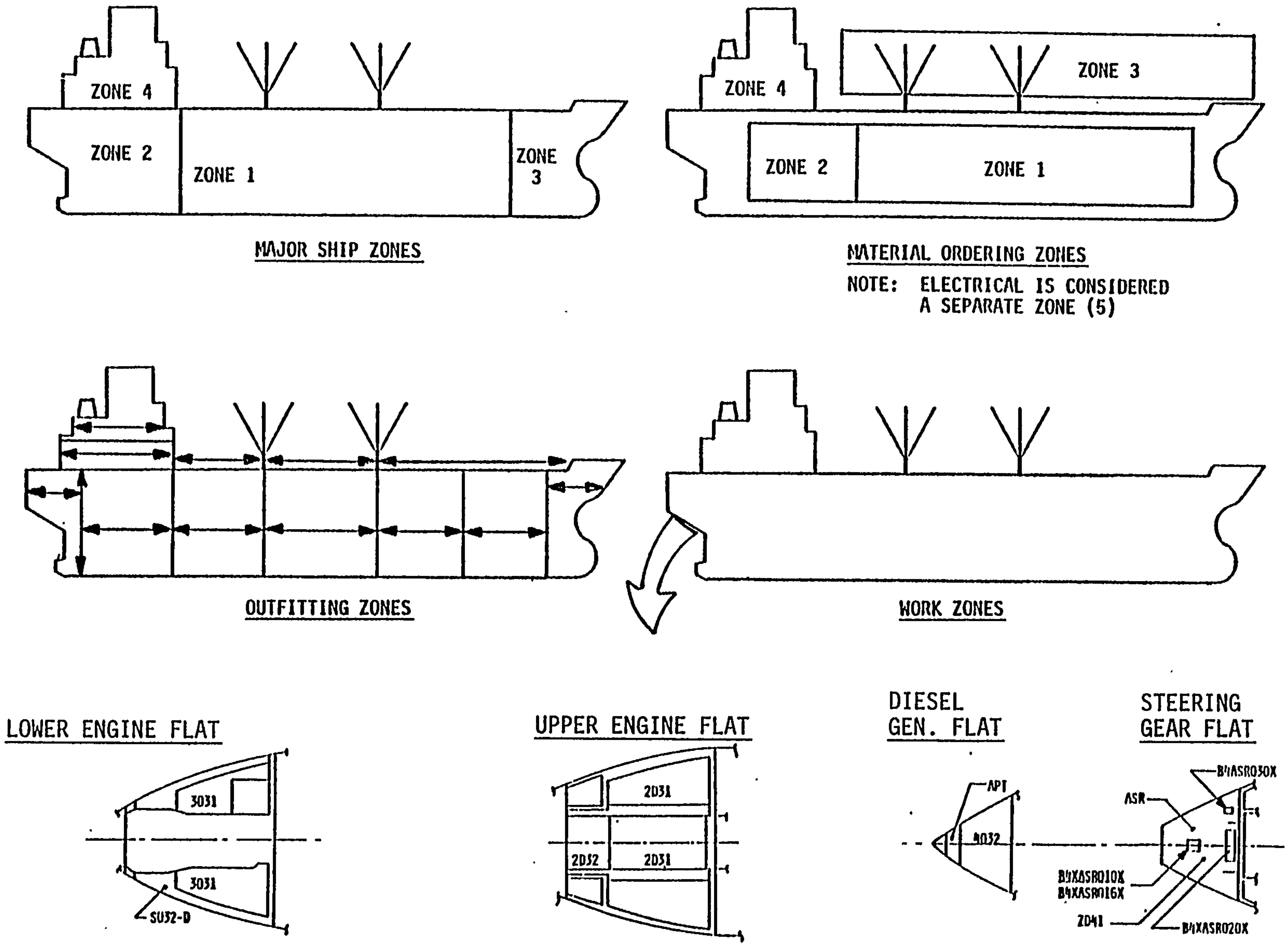


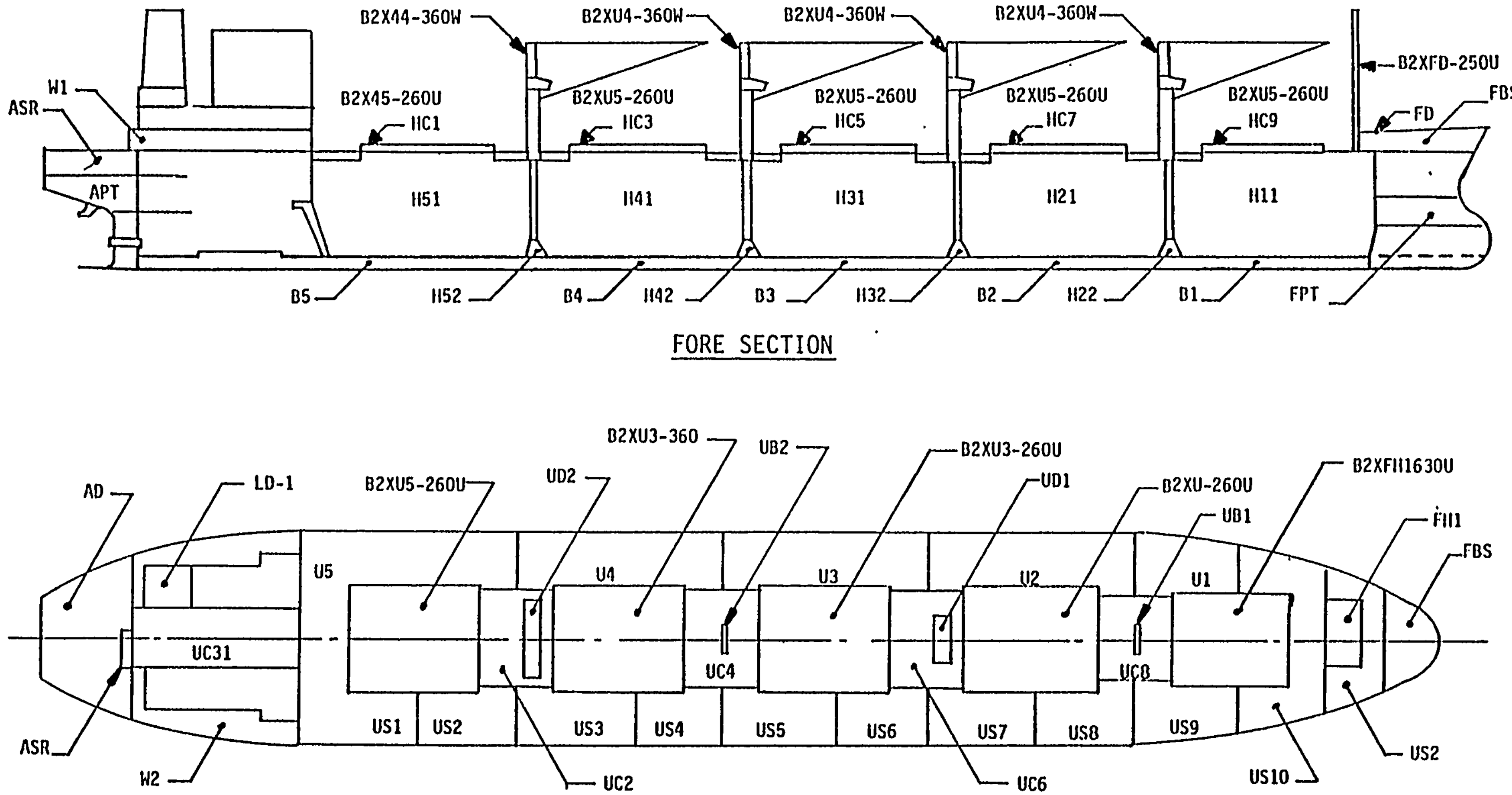
FIGURE 3-7 DIFFERENT SHIP ZONES

The system-oriented material lists (MLS) for each Material Ordering Zone are sent to the Material Procurement Department for scheduling and ordering. Because of the wealth of historical data accumulated by the IHI yards over the past decades and because of the unique relationships between these yards and subcontractor/suppliers (which generally reside in proximity to the yards), the yard procurement function is able to immediately construct valid lead-time and cost information.

The system diagrams developed by the Engineering Department are part of the second stage of design development which is called "Functional Design". This stage translates the Basic Design to the next logical level of development, i.e. Detail Design.

During the Detail Design stage the data from the functional design is converted into working-drawings of unit assemblies, sub-assemblies, detail parts and pieces, etc. Also at the detail design stage, an Outfitting Zone Plan is developed for the ship. This outfitting zone planning essentially sub-divides the major ship zones into smaller areas concerned with outfitting activities in the major ship sections, i.e. cargo hold, engine room, deck house, main deck, etc. An "Outfitting Zone" is simply a geographical area (3-dimensional) of the ship having no relation to a particular system. Instead all systems within a given area are encompassed by the zone boundaries. An Outfitting Zone can represent a portion of a deck, a portion of several decks, one or more compartments, parts of adjacent compartments, etc. Figure 3-8 illustrates the Outfitting Zones identified for one type of ship.

The criteria for sub-dividing the ship into outfitting zones are based on the hull breakdown (in the Hull Blocking Plan), and the identification of logical packages of outfitting work at each of the production



FORE SECTION

UPPER DECK

FIGURE 3-8

OUTFITTING ZONES

stages of sub-assembly, assembly and erection. This identification of work packages parallels the construction of the steel sub-assemblies and units since outfitting must be accomplished at precise periods in the hull construction schedule. As a consequence, Outfitting Zones are identified which correspond to the hull units specified in the Hull Blocking Plan.

With the identification and designation of Outfitting Zones, detailed material lists are formulated together with piece drawings for the manufacture of pipe pieces, piping arrangements, and outfitting pieces and sub-assemblies. Specific material lists are prepared for the manufacture of pipe (Material List for Pipe - MLP) and for other outfitting components (Material List for Components - MLC). These material lists and the associated piece drawings are eventually scheduled for production through the yard pipe or fabrication shops. Figures 3-9 and 3-10 present examples of these lists.

In addition to the above, the Detail Design effort also produces composite drawings showing the layout of all outfitting material in specific “Work Zones” (a further breakdown of the outfitting zones into small packages of outfitting work). These composite drawings show the interrelationship of the many different systems integral to the individual work zones together with details of mounting and joining. Figure 3-11 provides an example of a composite drawing.

Upon completion of the composite drawings, the final stage of design, Work Instruction Design, is initiated. This design stage produces drawings of outfitting components which are to be installed at different production stages, e.g. sub-assembly, assembly, erection,

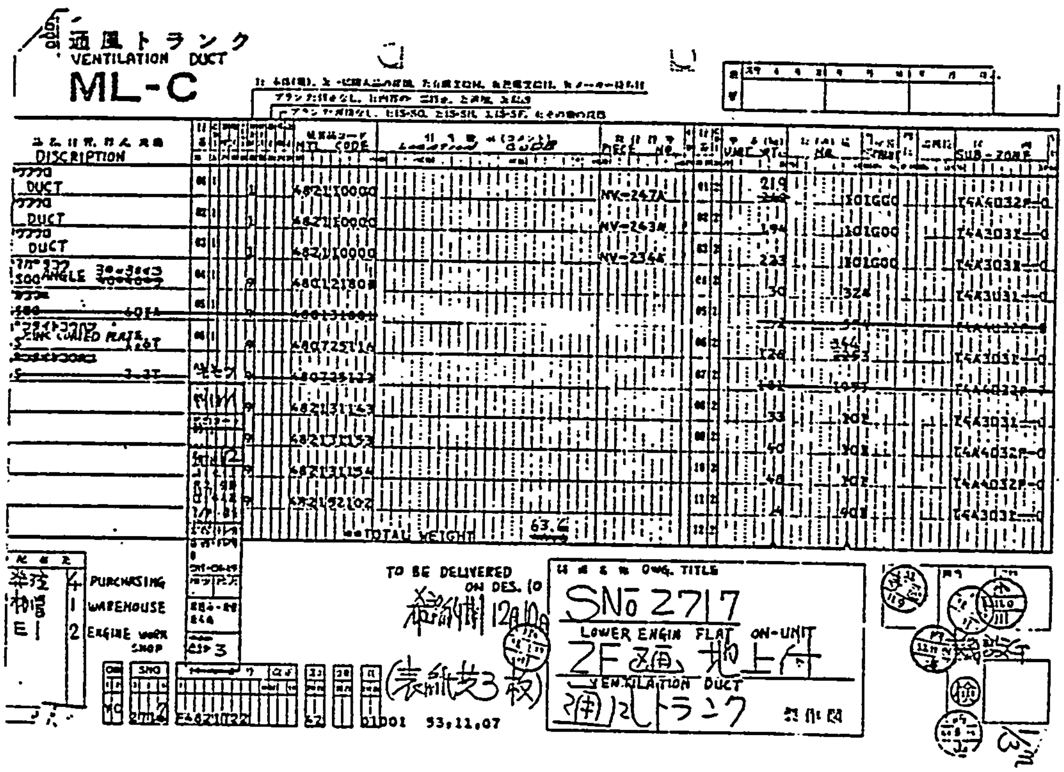
MATERIAL LIST FOR PIPE

MLP

DESCRIPTION	S NO	OUTFITTING CODE	C NO	MATERIAL CODE						WEIGHT
15A			94	161001	1			13	0	93.7
25A			94	161003	1			31	0	414.3
40A			94	161005	1			26	0	556.3
50A			94	161006	1			14	0	408.9
65A			94	161007	1			9	0	369.8
15B			94	162001	1			1	0	7.2
25B			94	162003	1			9	0	127.2
40B			94	152005	1			14	0	315.7
65B			94	162007	1			5	0	260.8
25C			94	162103	1			1	0	18.0
40C			94	162105	1			6	0	180.5
50C			94	162106	1			4	0	164.1
65C			94	162107	1			3	0	193.0
25CC			94	162118	1			1	0	18.0
40BB			94	162156	1			2	0	45.1
50BB			94	162157	1			2	0	59.8
65BB			94	162158	1			1	0	50.2
25CC NK			94	172022	1			2	0	35.0
40CC NK			94	172024	1			3	0	90.3
40CC AB			94	178024	1			1	0	30.1
40SC LR			94	184077	1			1	0	30.1
15B AB			94	188004	1			1	0	7.2
25B NK			94	188006	1			2	0	28.3
			94							
			94							
			94							
		TOTAL	94							3,499.6

FIGURE 3-9

MATERIAL LIST FOR PIPE



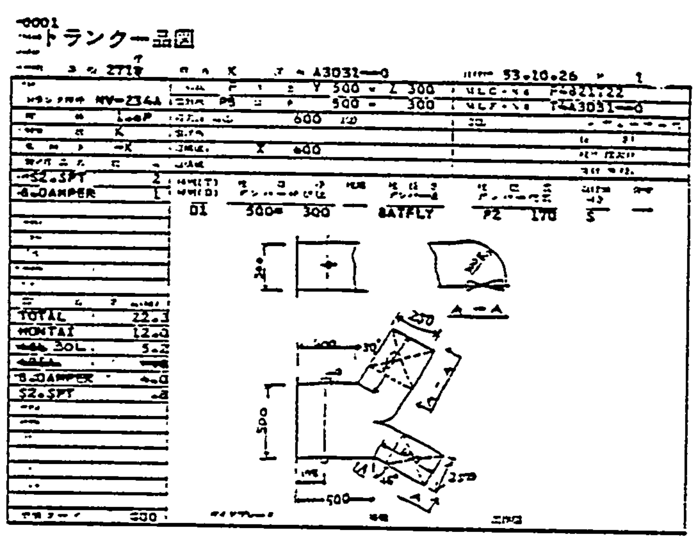


FIGURE 3-10

MATERIAL LIST FOR COMPONENTS

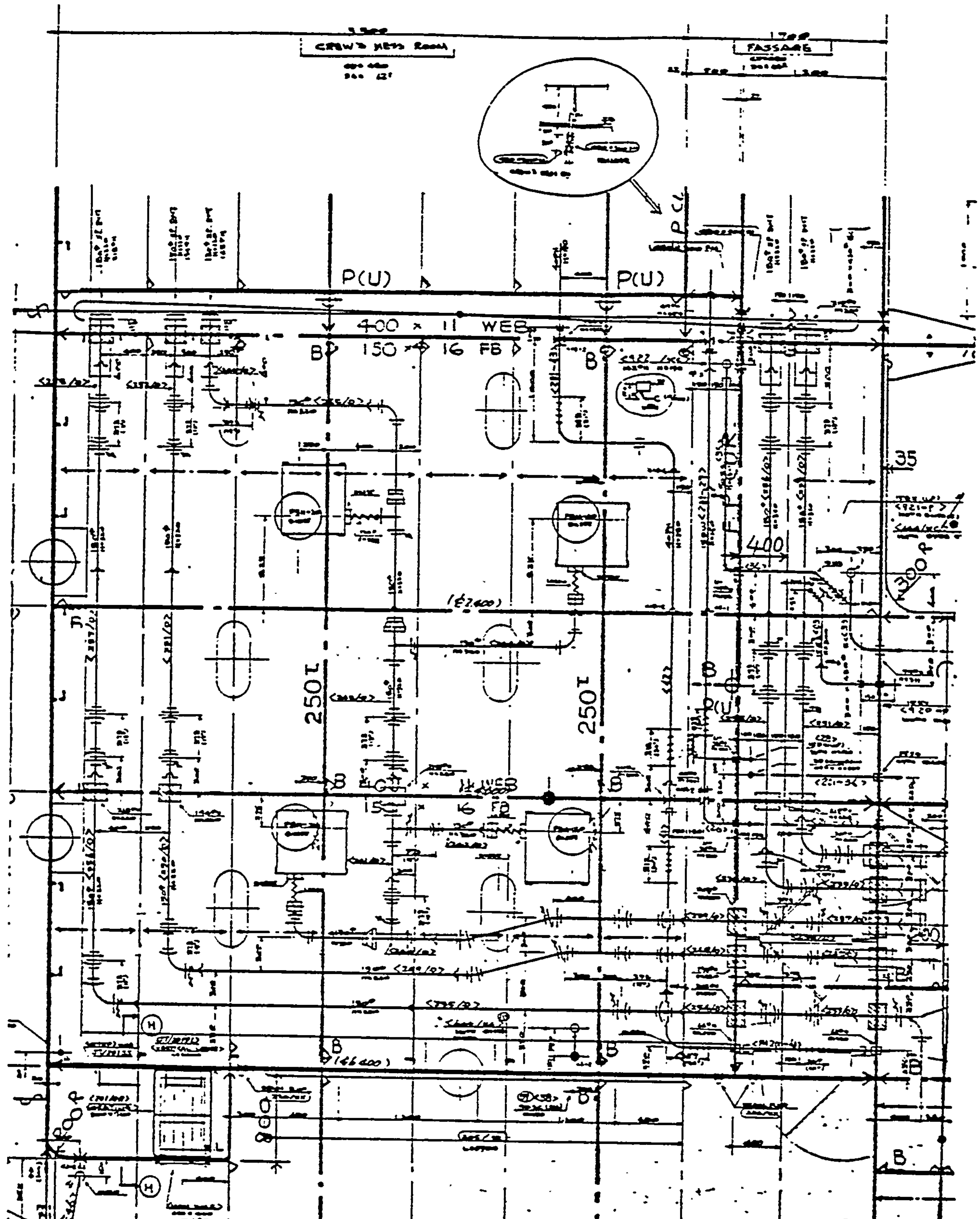


FIGURE 3-11

COMPOSITE DRAWING

after launch. Figure 3-12 illustrates this development from top-level design data to individual Work Instruction Drawings. Accompanying these drawings is another material list, the Material List for Fitting (MLF) which corresponds to the work to be accomplished at the production stage shown on the Work Instruction Drawing. This package of information describes the work to be done, the production stage at which it is to be done, and the list of materials which must be accumulated and present at the work site. Figures 3-73 and 3-14 provide examples of a Work “ Instruction Drawing and a Material List for Fitting, respectively.

The Work Instruction Drawing, the associated MLF, the procured components and the manufactured components (i.e. by the yard) comprise a specific work package or “pallet” as it is identified by IHI. All information and all related material is collected at the proper work site, at the proper--production work stage, and at the proper time interval to enable the outfitting of specific units, blocks, grand “blocks, or on-board the erected ship.

The “pallets” information and material correspond to the “work zones” established for a given outfitting zone. These outfitting activities are rigorously scheduled to continuously parallel the hull construction sub-assembly, assembly and erection schedules.

The preparation of the various material lists, as shown in Figure 3-15, takes place in stages working toward completing the information necessary for production. At each of these stages, exact material requirements are fed-back to the basic material list. This feedback is an important step because the accuracy of the basic material list is important for estimating the cost of subsequent ships in a series.

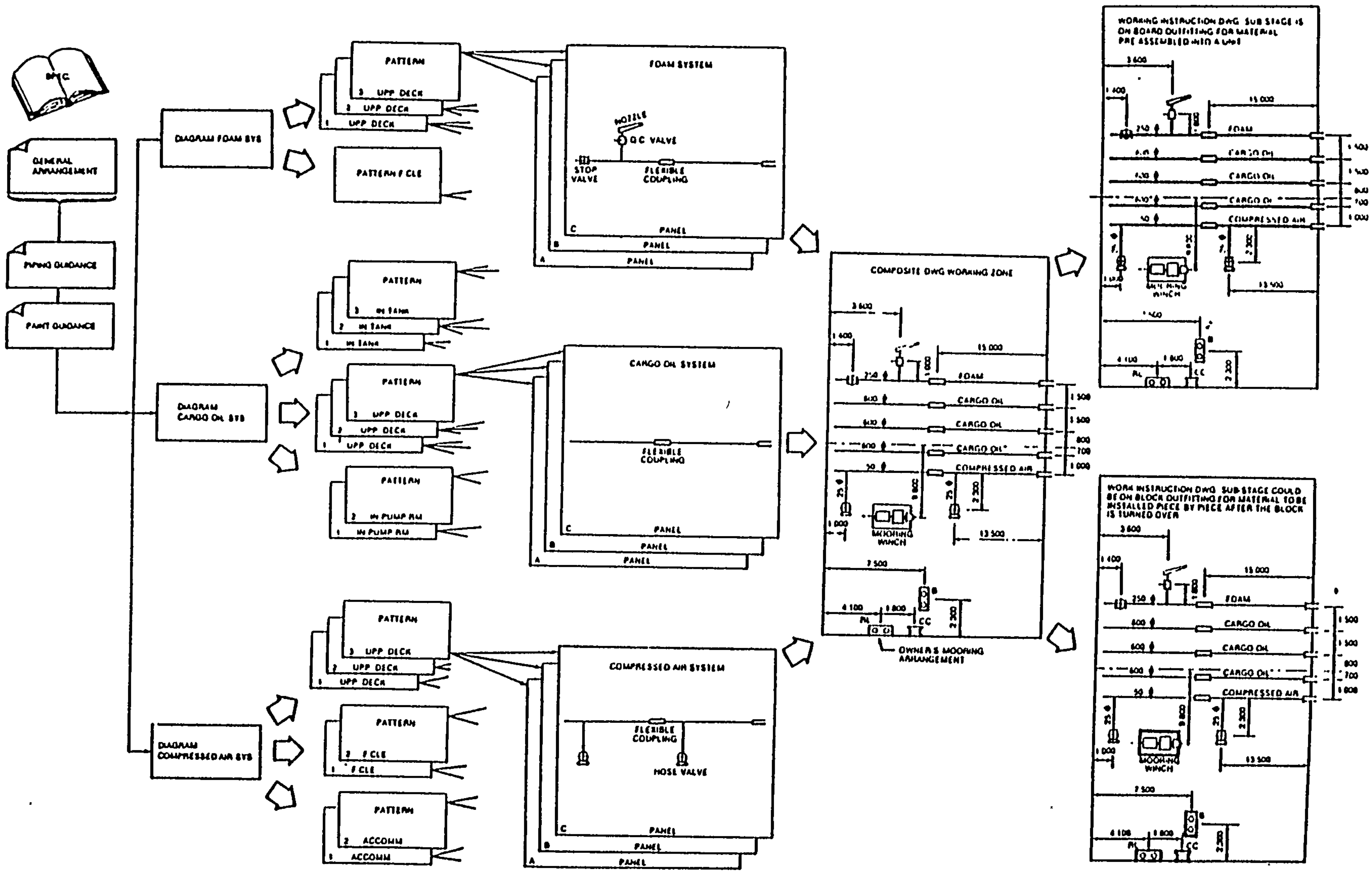


FIGURE 3-12

OUTFITTING DESIGN DEVELOPMENT

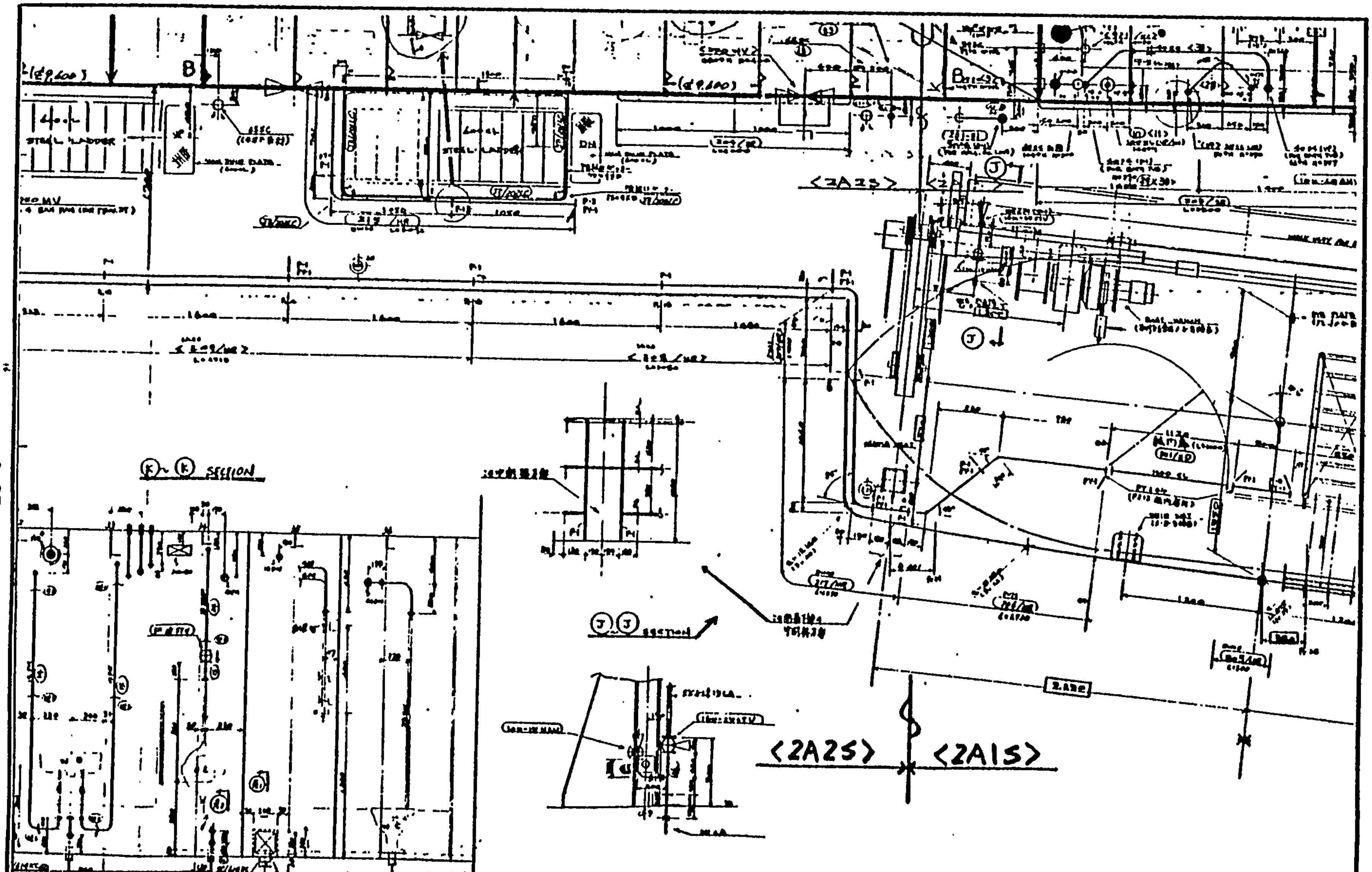


FIGURE 3-13

WORK INSTRUCTION DRAWING

A : Information for unit assembly.
F : Fabrication sign.
L : Temporary location sign for next stage.
U : unit of quantity
W : Indication of weight.

M L F

Date
19. 05. 11

DESCRIPTION	A	Piece No	F	L	Specifications	Qty	U	W	Weight	Paint	Ref.Dwg No / MLF No for TLM	Mtl code	A K	Remarks
BUTTERFLY VALVE(MANUAL)		SW-425V			FC25 SCS13 5K ♦ 200	10	1	1	240	D42	N4044000	1404490000		♦
BUTTERFLY VALVE(MANUAL)		SW-426V			FC25 SCS13 5K ♦ 200	10	1	1	240	D42	N4044000	1404490000		♦
BUTTERFLY VALVE(MANUAL)		SW-472V			FC25 SCS13 5K ♦ 125	10	1	1	140	D42	N4044000A	1404490000		♦
BLIND FLANGE SS41 GALV.FB 5K 80SSO						10	1	1	29	R44		44060101301	A	♦
WATER FILTER		SW-403S			5K-200C (200X250) FIREGS	10	1	1	1410	D42	N408240OC	1408250900		♦
WATER FILTER		SW-404S			5K-200C (200X250) FIREGS	10	1	1	1410	D42	N408240OC	1408250900		♦
FIRE & G S PUMP		MA-057AA			VEC 180/300M3/H ♦ 80/35M	10	1		10000		N4451160A	1445116000		♦
FIRE & G S PUMP		MA-057AB			VEC 180/300M3/H ♦ 80/35M	10	1		10000		N4451160A	1445116000		♦
MOTOR (FIRE & G S P)		P/FGR-M			75KW 1800RPM TE V B	20	1		13200		N4451170	1445117000		♦
PIPE BAND SUPPORT					N=24	10	1	1	1872		F4634803	2463400000		♦
ORIFICE		SW-401W			10K ♦ 125	10	1	1	07	D42	N469930OE	1469930000		♦
ORIFICE		SW-402W			10K ♦ 125 (D=39)	10	1	1	01	NOP	N469930OD	1469930000		♦
VERTICAL LADDER		NG-100V			VFS-5 L/800	10	1	1	110	D33	F4830212	2483620000		♦
VERTICAL LADDER		NG-101V			VFS-5 L/950	10	1	1	131	D33	F4830212	2483620000		♦
FLOOR & GRATING		NG-070C				10	1	1	905		F4831010	2483100000		♦

S. No.	MLF - No	Req. date	next stage	Work Dwg. No.	Shop		BClength	Total wt.	Control wt.	Erect wt.	Page
2688	84Y057---0	79 06 01	T40PS315-0	2U01 .3	7	42 PNO.226		785 5171	785 5171	785 5171	5

(2228)

FIGURE 3-14

MATERIAL LIST FOR FITTING

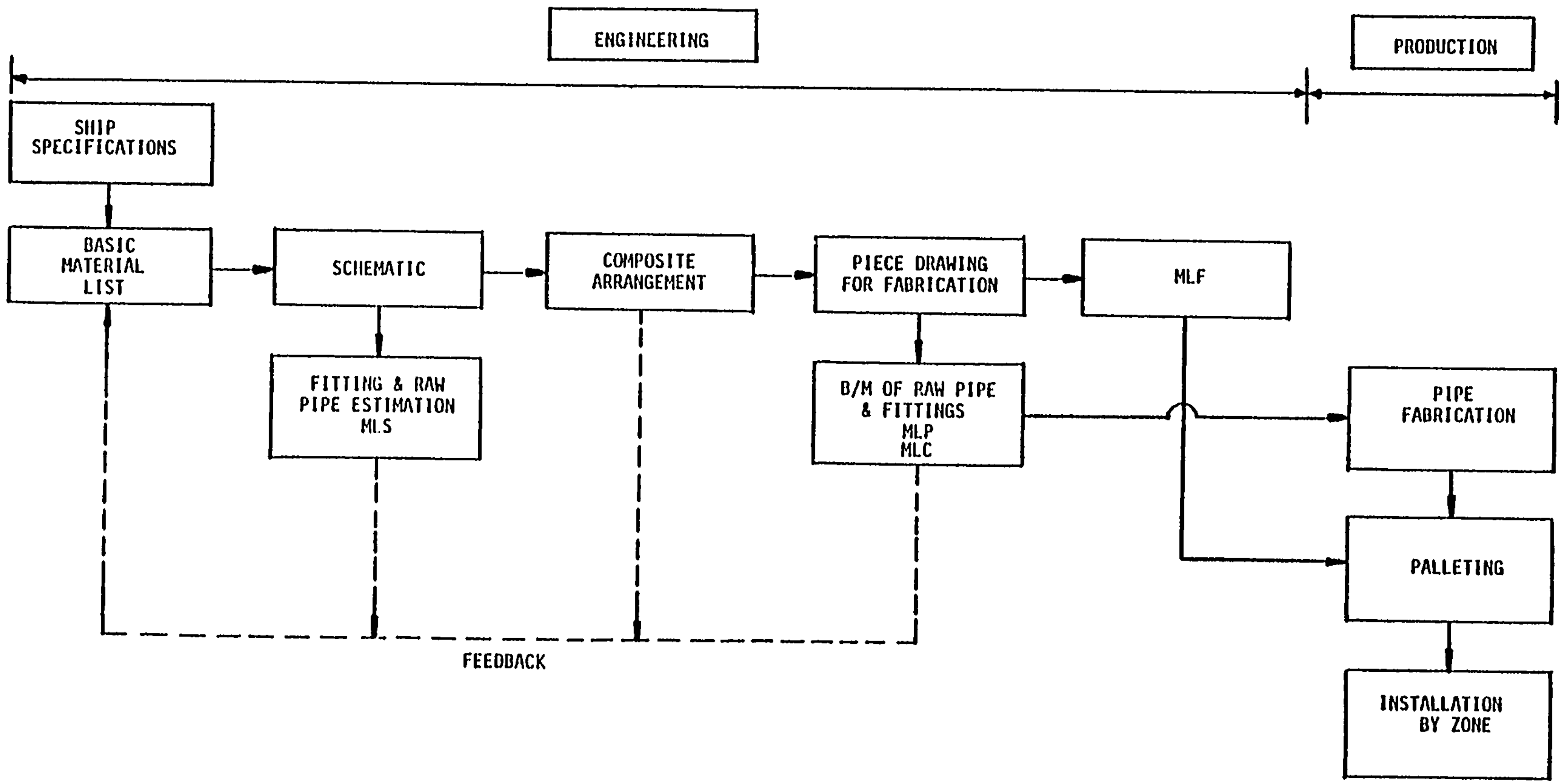


FIGURE 3-15

DEVELOPMENT OF MATERIAL LISTS

3.4.2 Composite Drawing System

In IHI composite drawings are the primary source of information for the pre-outfitting of entire zones of a ship. A zone may be composed of one or more units and will often contain portions of many different piping systems as well as other outfitting items involving electrical, mechanical, ventilation, deck fittings, etc.

Another name for the composite drawing system is the compartment outfitting method. All outfitting systems are shown in an outfitting arrangement drawing based on a compartment or zone of the vessel. This is in contrast to the system by system approach, which usually shows one or more entire piping system for a major portion of the hull, or even for the entire vessel. The composite drawing shows all material in a zone; therefore it is useful to the foreman for systems interface reference and daily progress monitoring.

IHI has realized many benefits from the use of composite drawings for outfitting, especially in the important area of piping. Through a coordinator between outfitting design sections, all interferences are dealt with on a day to day basis. The composite drawings are prepared to a drawing supply schedule which is relatively standard for a basic vessel type. As nearly as possible, all outfitting sections simultaneously work on drawings for the same area of the ship.

A Design Procedure and Drawing Supply Schedule is built into the Master Schedule for every vessel, or series of vessels, designed and built in an IHI shipyard. Considered a management standard, it provides enough lead time before actual start of fabrication for the necessary design and engineering work that must precede the actual fabrication, assembly, erection and outfitting activities.

At approximately one year before the keel is laid, a month or so is reserved for preliminary study of all outfitting requirements. During this process there is much interaction between all sections of the shipyard design office. The study precedes the preparation of the master piping diagram as well as all other outfitting major arrangements. Following the completion of these, and at approximately six months before the start of outfitting, a composite study is made for outfitting. This three to four month task results in the composite drawings required for sub-assembly of piping or installation of components in a hull unit.

Concurrent with the preparation of the composite drawings, the material lists (MLF and MLP) are prepared. The MLF facilitates material gathering in advance of fitting. It corresponds to the fitting drawing which shows all material in a compartment or work zone. All outfitting pieces are numbered designating the compartment, system, and whether the parts are to be fitted on-unit or on-board. On-unit or on-board fitting designation may be made with a separate drawing (See Figure 3-16).

Due to limited space, composite drawings do not give all information necessary to fabricate pipes, therefore, separate pipe piece drawings are made. Piece drawings are actually breakdowns of a composite drawing showing each piece and fitting. A material list (MLP) is included on the piece drawing to show size, type, quantity, and material specification. This type of drawing is usually a three-dimensional view. Figure 3-17 provides an example of the kind of pipe piece drawing used by IHI.

In many cases, in order to eliminate duplicate work in the design office, the composite drawing is utilized for the fitting drawings. For example, parts of a large composite drawing may be photographically

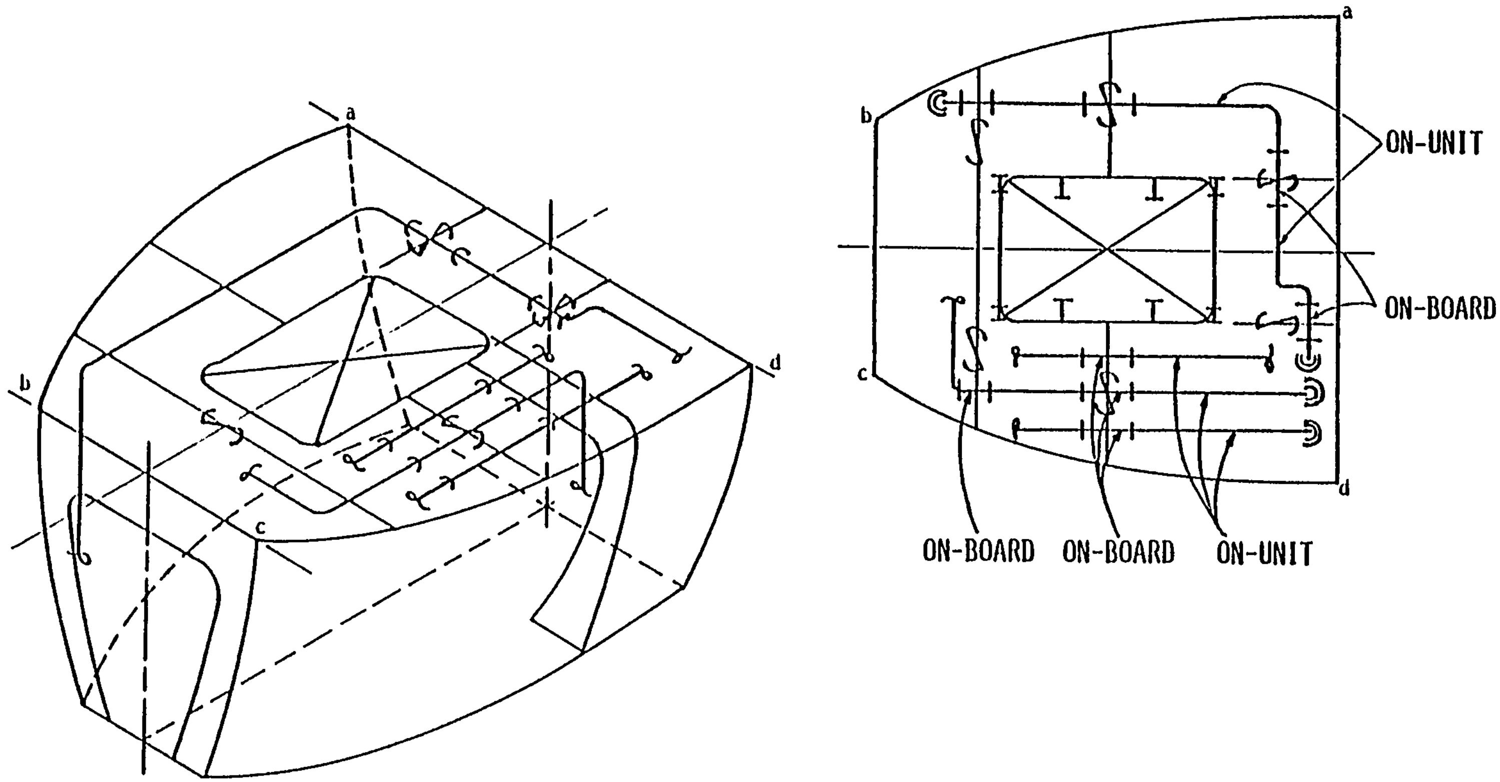
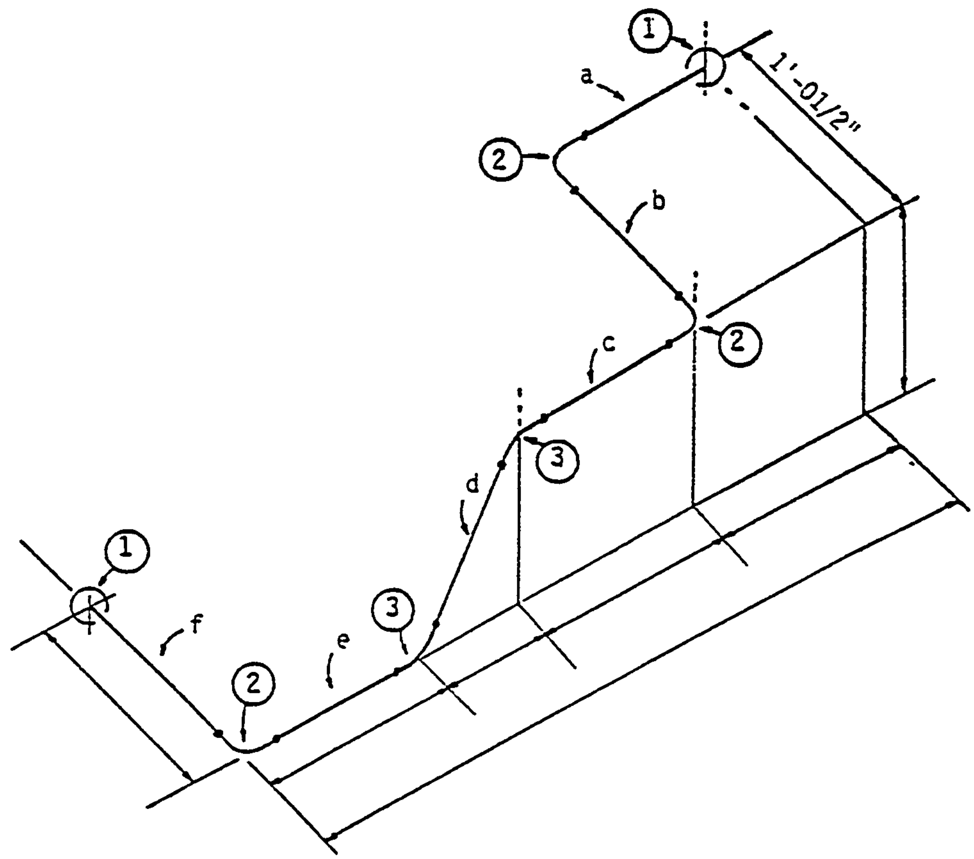


FIGURE 3-16

EXAMPLE OF DRAWING FOR DESIGNATION OF ON-UNIT OR ON-BOARD FITTING



MATERIAL LIST

QTY.	DESCRIPTION	MAT'L	PC. MK. RESULTS
2	3" 150# Flg	FS	1 FF
2	3" 45^0 Ell Sch 40	BLK	3 BW
3	3" 90^0 Ell Sch 40	BLK	2 LR BW
1	3" Sch 40 Pipe 2'1-1/8"	BLK	a
1	3" Sch 40 Pipe 0'3-1/2"	BLK	b
1	3" Sch 40 Pipe 3'9-1/2"	BLK	c
1	3" Sch 40 Pipe 3'0-1/16"	BLK	d
1	3" Sch 40 Pipe 0'5-9/16"	BLK	e
1	3" Sch 40 Pipe 0'2-3/8"	BLK	f

FIGURE 3-17

EXAMPLE OF PIPE PIECE DRAWING
(WITHOUT DIMENSIONS)

reproduced to scale and used by outfitting groups, making re-drawing or tracing unnecessary.

Just as each stage of the design process more clearly defines material requirements, the work instruction drawings, made from the composite drawings, show only those components to be installed at a specific production stage. This may be done by darkening or coloring in the appropriate lines on the composite drawing. When required, assembly instructions are included. In this manner, the necessary information and instructions to the production group responsible for the installation of material at a specific stage are provided.

The drawing package that is ultimately given to Production consists of the composite or compartment drawing, the fitting drawing, work instruction drawings and the MLF. In the production process, the foremen use the composite for reference, whereas, the workmen rely on the fitting drawings, the work instruction drawings, and the MLF.

3.5 ADDITIONAL DESIGN AND ENGINEERING PLANNING

The Hull Construction and Outfit planning discussed in the foregoing pages combine the aspects of design and production into a thoroughly defined set of working drawings and plans necessary for the manufacture of the hull assembly units, the outfitting of those units and the erection and outfitting of the entire ship. This discussion has purposely ommitted some types of planning (that occur simultaneously) in order to simplify the design process. However, it is important to cover these other planning aspects to complete the overview of this involved process.

Throughout the planning occurring in the breakdown of the hull into its constituent bits and pieces and the outfit planning, a staff

of Accuracy Control Engineers assist the planners and designers and formulate discrete accuracy control requirements for each unit, sub-assembly and piece part. These engineers develop detailed data concerning the vital dimensions and points of measurement to ensure that all manufactured components of the ship meet the highest accuracy standards possible. Additionally, these engineers develop a plan or scheme for providing added material at each stage of production to ensure that errors can be corrected without rework of the part and to provide for neat cutting at the various sub-assembly, assembly and erection stages. Accuracy Control Engineers also define the base lines which must be used for assembly alignment to keep maximum accuracy throughout the production, assembly and erection processes. The selection and application of process standards to the fabrication processes is also the responsibility of these engineers.

The objective of this accuracy planning is to effect the highest production efficiency by ensuring that each of the fabricated and assembled components meet prescribed standards and require no re-work as the material flows through the production process. This achievement of high accuracy reduces the amount of work required at the erection stage and ensures that the completed ship will meet or exceed all quality standards and will be in true alignment as required by design specifications.

The details of this accuracy control planning are contained in two Technology Transfer Program Reports: Livingston’s Final Report on Quality Assurance No. L2123-5.1-4-1, and the Special Report on Accuracy Control Planning for Hull Construction, No. L2123-5.1-4-2.

Other plans are prepared by workshop engineering personnel to detail the methods for facilitating work during the erection stage and during on-board outfitting. This planning is called "Field Planning" and consists of the following types of plans.

Plan for temporary holes (in the hull during erection)

Plan for ventilation & cooling of the hull on the ways

Plan for supply of electrical power and gas lines

Plan for stools arrangement on the ways

Plan for equipment access on-board and on working staging

Plan for standard shipwrighting techniques

Plan for maintaining shaft alignment considering the initial hogging of the aft and forward ship sections

Plan for tank arrangement and testing

Plan for final dimension check items

Plan for disposal of temporary pieces for construction

3.6 DESIGN CHANGE CONTROL

System design changes occur because of regulatory body requirements, owner requirements, builder changes due to design changes or errors, builder changes due to production errors or methods changes, or vendor changes because of errors in drawing, changes in material or equipment, etc.

In IHI, the system for design change is initiated in the design department, regardless of the source of the change. In order to minimize rework and rescheduling, preliminary information regarding the change is accomplished quickly. To facilitate smooth incorporation of the design change into the total system, changes that have a big influence on schedule are dealt with at meetings held for the specific

purpose of discussing design changes. On items of change having an effect on future vessels, information will be fed back into the design process.

Design changes are classified into two categories according to the physical progress at the time initiated: before and after completion of marking.

In the case of a change occurring before marking, the design change is treated very routinely, but a special process is utilized in the case of a change occurring after marking. In either case, implementation of the design change is controlled by a production control engineer who is aware of the progress of the affected item.

The information necessary for production to smoothly handle a design change is put on an information sheet made by Production Planning and Engineering Groups and issued to concerned sections (See Figure 3-18). The information sheet includes the following data:

1. Necessary material shape and size
2. Material number
3. Material weight and cutting length/welding length
4. Changes to work schedule
5. Destination of material

In summary, two parallel systems exist for handling design changes. The preliminary information system is immediately effected so that the change can be ordered to production before any rework is necessary. The formal information system is then activated to update all records and make all necessary notifications (refer to Figure 3-19). Thus, quick action to minimize cost and formal action to keep all records

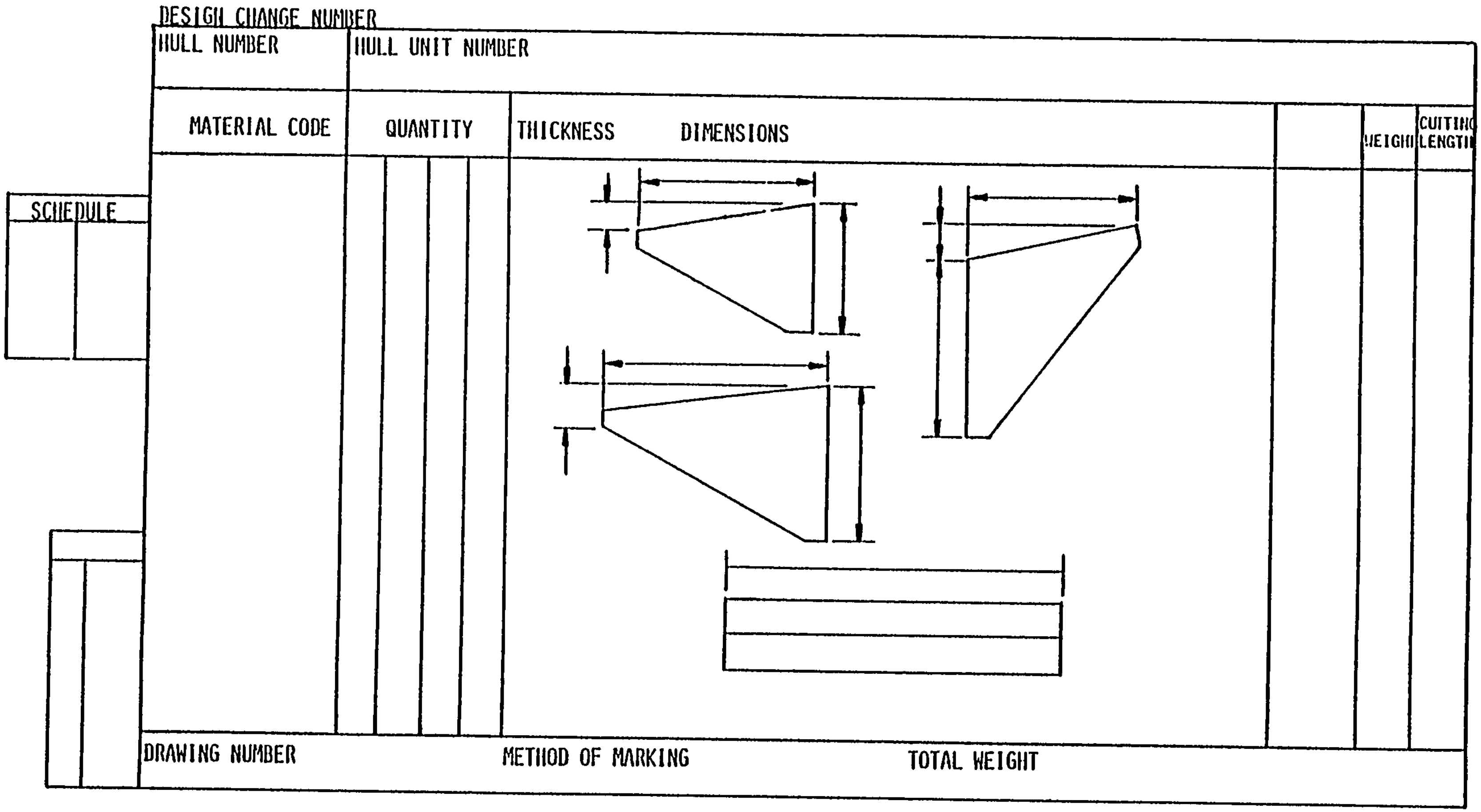


FIGURE 3-18

EXAMPLE OF INFORMATION SHEET FOR DESIGN CHANGE
(WITHOUT DIMENSIONS)

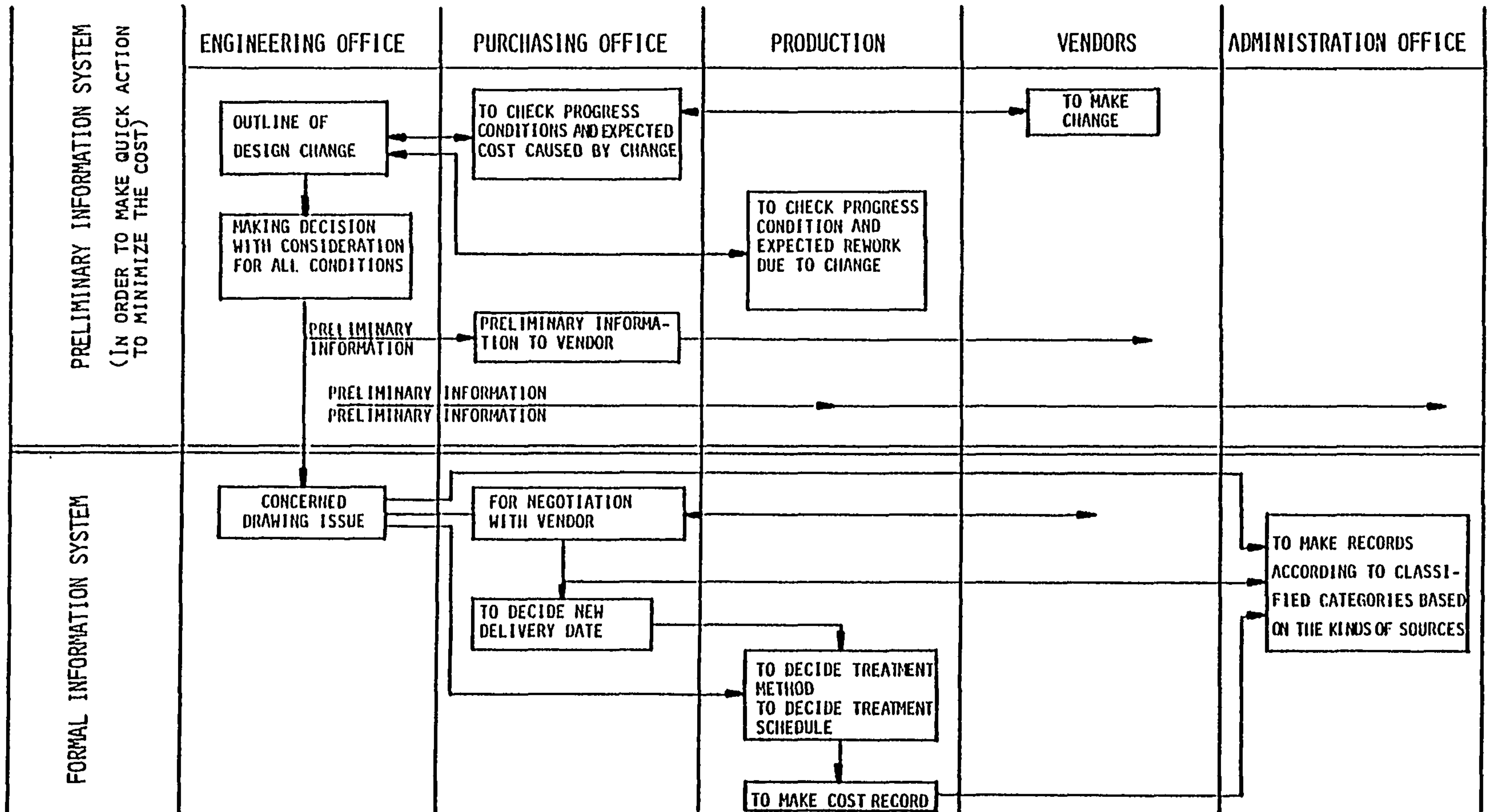


FIGURE 3-19

INFORMATION FLOW FOR DESIGN CHANGE

accurate are the two main objectives of the design change control system at IHI.

Effects on Computerization

In the IHI Computer System (IHICS) for hull design, all design changes are quickly fed back into the system to minimize the negative effects of the change. The response time and flexibility inherent in the IHI system allows a production design change to be effected almost as quickly as if the change occurred during the period of initial ship design. The program is designed so that production corrections caused by design changes are minimized.

Descriptions of lines do not necessarily have to be changed because of changes to data on longitudinals such as offsets, material dimensions and cutouts. Such descriptions are executed by the system at both the design phase and the part generation phase. Actual generation of physical data of parts can be postponed up to the execution of parts generation. The shapes of the cutouts at longitudinal frames is generated after all inputs to the system.

Standard design data is independent from the computer program. Registration of standard design data changes is the responsibility of the designers. The system provides for simplified updating of all design data.

3.7 ENGINEERING ACTIVITIES--LAUNCHING TO DELIVERY

As is typical of practically all shipyards, the Shipyard Design Department is involved as an aid to Production during the time from launching through delivery of the vessel. Some of the main activities are:

Launching

Incline Tests

Deadweight Measurement (Ship's Light Weight)

Plan of Equipment Testing and Sea Trials

Performance Confirmation

Ship's Operation Manuals

Finish Drawings to Reflect All Modification (Ship's Copy)

Provide Gross Tonnage Data According to Worldwide Requirements

SECTION 4

COMPUTER AIDED DESIGN

4.1 GENERAL

Since IHI entered the field of computer, aided ship design and manufacture, several main systems have been developed and extensively utilized at the IHI yards. These systems have applications throughout the design and production processes beginning with the Basic Design at the Head Office in Tokyo through the development of the Key Plans and the Yard Plans at the shipyard. These main systems are the result of breaking down the engineering work to be done into simple processes. This process definition facilitated the building up of program modules which perform the necessary data processing according to the type of work to be done and the required output. In this manner; the IHI computerization group has developed an integrated system of design oriented programs that share a common data base but perform independently to provide the data necessary for all phases of ship design and automated fabrication.

In the broad area of Design and Engineering, computerization is heavily relied upon in the Basic Design stage to perform structural analysis, propulsion performance analysis and maneuverability analysis. As the design progresses toward development of the Key Plans, all necessary ship's calculations for naval architectural data are also performed. As the Key Plans are finalized and the Yard Plans are begun, the Hull Design system is fully utilized from the fairing of ship's lines to hull piece design. Systems for outfitting design are also employed.

Production Engineering and Material management also rely on computerized systems. Purchasing and issuing material are functions of the Steel Plate Control System. There is also a Material Control System for new ship construction. The design oriented functions for Production Engineering are for Hull Piece Drawing, Nesting of Hull Plates, Hull Piece/Parts Control System and a Pipe Processing plan.

Scheduling and manufacturing utilize computerization for Hull Construction Scheduling, Outfitting Scheduling, Manhour Calculation, N/C (Numerical Control) High Speed Marking System, N/C Gas Cutting System, and N/C Frame Bending and Pipe Bending.

The following paragraphs deal with the computer systems, modules and programs directly involved in the design development, fabrication of the hull and outfitting of the vessel.

4.2 MAIN IHI SYSTEMS FOR COMPUTER AIDED DESIGN

IHICS, or Integrated Hull Information Control System, is a series of program packages which assists engineers in the design and production engineering for hull construction, and also provides information necessary for production.

IHICS resulted from the necessity to standardize as much design data as possible and to correlate these data with the established production processes of the IHI shipyards. These data include Numerical Control, Production Engineering, and Production Control data.

IHICS provides the following:

Generation of engineering and production data from a small volume of input data prepared by engineers.

Assistance to engineers in design and production engineering activities.

Creation of a data base which supplies the manufacturing division with production engineering data, numerical control data and piece lists for each stage of production.

The IHICS system is structured to provide a maximum of output data from a minimum of input data. Input at the Preliminary Design stage, the Key Plan Design stage, the Yard Plan Design stage and the Production Engineering stage represents a small percentage in relation to the total data created within the system.

IHICS is composed of the following three sub-systems: Basic Data Creation, Section Design and Production Engineering. Figure 4-1 describes these sub-systems in terms of their respective component programs in relation to the data base. Each of the program's functions are outlined in Table T4-1 which also lists the program outputs.

Z PLATE is a program for analysis of elastic plate structures under plane stress conditions. It is especially applicable to three dimensional structures constructed with plates. As a checking device, the calculated data results are examined by using a high speed plotter. and a graphic display.

Z VIBRA is a program for analysis of vibrational responses in the elastic range of three dimensional framed structures under forced vibration.

SPECS or Ship's Preliminary and Exact Calculations System, is applied to detailed design in ship's preliminary hull calculations on hull form and capacity. In addition, calculations are made to provide information necessary for ship's operation and sea trials. outputs of most of the sub-programs of this system generate drawings and curves as well as tabular data. Examples of actual output can be found in Appendix E.

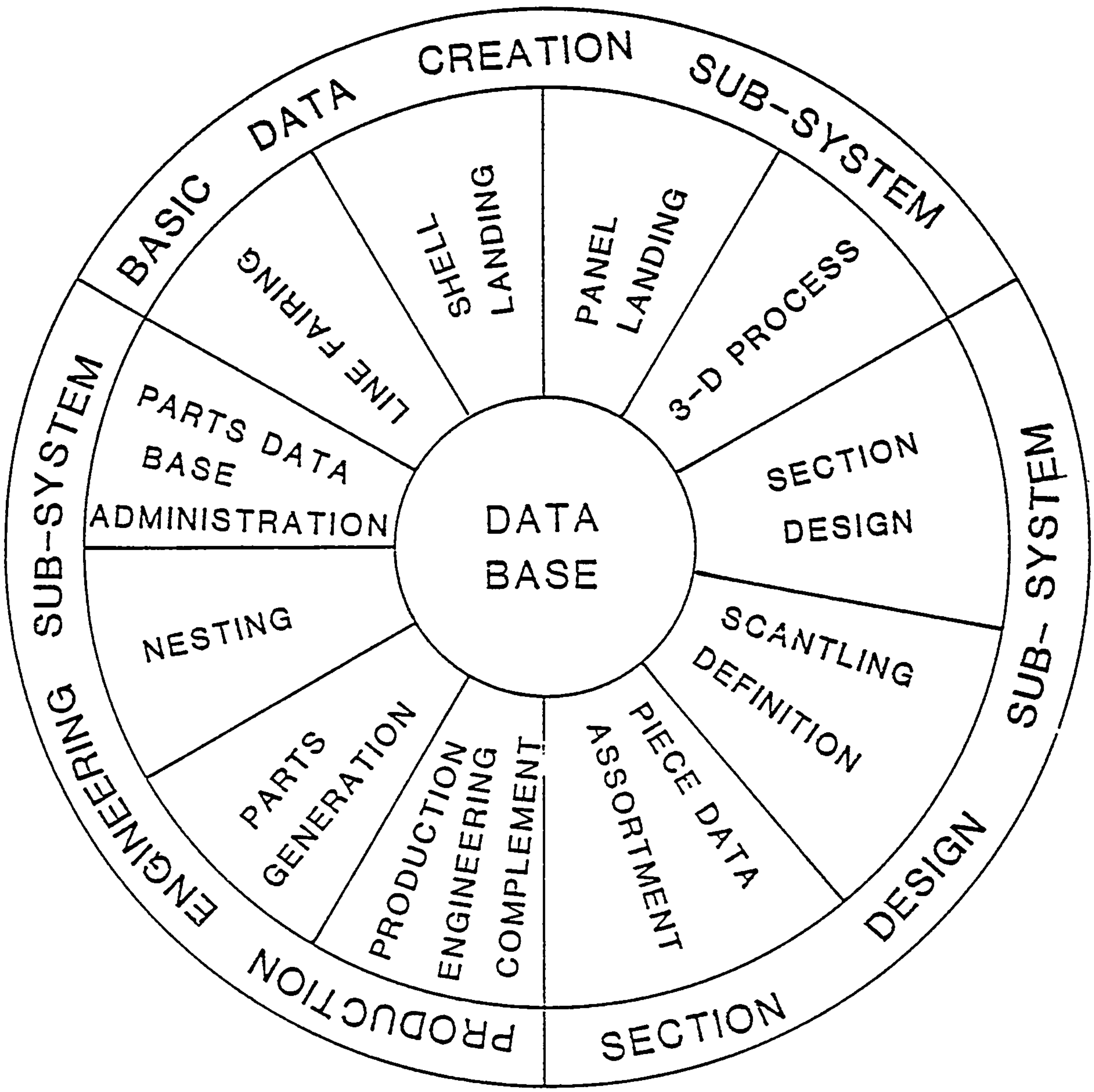


FIGURE 4-1

COMPONENTS OF IHICS

SUB-SYSTEM	MODULE	- Component Programs	OUTPUTS
BASIC DATA CREATION	FAIRING	- Lines Fairing Program	*Geometry Data Base, Panel Data Base, Scantling Data Base *Complete Drawing of any Desired Portion of Lines Drawing *Book of Mold Loft Offsets *Structural Body Plan (1/10, 1/50) *Shell Expansion Plan *Panel Plan (Deck, Bulkhead, Flat, etc.)
	SHELL LANDING	- Seam/Butt Landing Program - Longitudinals Landing Program - Scantling Definition Program	
	PANEL LANDING	- Seam/Butt Landing Program - Longitudinal Landing Program - Scantling Definition Program	
	3-D PROCESS	- Panel Definition Program - Compartment Definition Program - Cut Plane Program - Panel Composition	
SECTION DESIGN	SECTION DESIGN	- Web Figure Definition - Stiffener & Joint Arrangement on Web	*Section Plan (1/10, 1/50) *Piece Control Data List - Piece List for each assembly unit - Includes piece name, quantity , scantling, weight, piece drawing format, fabrication process and other production control data - Facilities data correction
	SCANTLING DESIGN	- Web/Face Plate Scantling Definition - Stiffener Scantling	
	SCANTLING DEFINITION	- Web/Face Plate Scantling Definition - Stiffener Scantling	
	PIECE DATA ASSORTMENT	- Piece Data Assortment Program	
PRODUCTION ENGINEERING	EDITING PROGRAM	- Part Program Generator . - Plate Edge Modifier Program	*Piece Drawing (including Tabular Format) *Numerical Control Data/Tape *Piece List for each Stage of Production *Template for Bending (Shell Plate and Longitudinal Frame) *Unit Marking Data for Shell *Jig Heights for Curved Shell Unit Assembly
	PART GENERATION	- Shell Plate Development and Assembling Data Calculation (SHELL) - Longitudinal/Transverse Frame Development (LODACS) - Internal Structure Development (Line System)	
	NESTING PROGRAM	- Manual Nesting Program - Interactive Nesting Program by CADS - Post Processor for Numerical Control Machines	
	PART DATA BASE ADMINISTRATION	- Part Data Base Handler - Piece List Editing Program for: *Fabrication *Subassembly *Assembly *Erection	

TABLE T4-1

FUNCTIONS OF COMPONENTS OF IHICS

FAIRING is the system that performs lines fairing by utilizing a method of interpolation called “N-Curve”, which stands for Natural Curve. This method is capable of expressing a straight line, a true circle (arc) and a compound straight line with a knuckle point, as well as a natural curve.

The SHELL system constitutes an integrated and computerized data processing system which provides variously highly accurate data pertaining to all the processes involved in the production of curved shell units. This system covers shell plate development, preparation of templates for bending, unit marking for on-jig assembly, and jig height calculations. Through utilization of the common data base the SHELL system provides flexibility for the planning engineers in that it provides the most suitable inputs in terms of accuracy and workability during the production process. Standardization of production technologies and methodologies enables this system to be used across the board at all IHI shipyards. Table T4-2 provides a summary of the characteristics of SHELL.

LODACS, LOngitudinal frame Developing And Conducting System, is a computerized system designed to deal mainly with the development and processing of hull panel stiffeners such as transverse frames and longitudinal frames with their respective end brackets. The added capability to handle the end members was provided mainly because these members are always connected to the frames and have elements which determine the cutout shapes of frames. Also, it not only enables the system to simultaneously process the data common to the frames and end members by a single input operation, but also provides the ability to process either the frame or end member independently.

SUMMARY OF CHARACTERISTICS OF SHELL

1.) Composite system for geometrical calculations and data processing relevant to the production of a curved shell unit.

2.) High level of accuracy in terms of the following:

*Formal checking of curved plates is made easier due to setting of bending templates at right angles to the mean curve of the plate.

*Simplified logic (algorithmic) calculations and uniform display of outputs i.e.concurrent points are plotted and joined by straight lines.

*Utilization of the cut-plane method of developing a curved shell plate in the view that best displays the characteristics of its curvature.

3.) Improvement on workability and accuracy in the assembly stage because the various working practices in the shop are taken into account.

4.) Accuracy control data relating to unit dimensions, diagonal dimensions, rate of curvature on seam or at butt, etc. are output.

5.) Main data file of offsets with separate peripheral data files facilitates file maintenance or data collection.

6.) Easy recording of feedback data, such as locked in stress from press or heating, which will be useful in future applications.

TABLE T4-2

The scope of application of this system covers the frames and end members to be fitted to the side shell, upper deck, longitudinal bulkheads and various flat decks. Exceptions to the application of this system are the extremely complex portions of the ends of the bow and stern.

LODACS also provides automatic generation of the data for secondary members such as flat bars and face plates. The computing of weight, center of gravity and cutting length is also provided and these results are added to file. Curved frame bending lines which are to be made straight after bending are also computed by this system.

4.3 COMPUTER AIDED DESIGN SYSTEM FOR PIPING

At IHI, computer aided design is utilized in the outfitting of vessels. Piping systems are automatically designed by the CADS system which is capable of designing new piping modules and modification of these modules when necessary. In addition to the automatically designed modules, the CADS system allows for input of manally drafted sketches of piping systems which will be processed and finalized as a usable design.

The basic flow of information into and from the CADS piping design system is outlined in Figure 4-2. Inputs include completed basic design data such as machinery arrangement, preliminary (rough) piping plans, piping service system description, and reference drawing identification. Standard data, schedules and piping data from similar or sister ships is also input.

The CADS system consists of parts data for the ship, drawing symbols, and master file data for piping practices and parts dimensions.

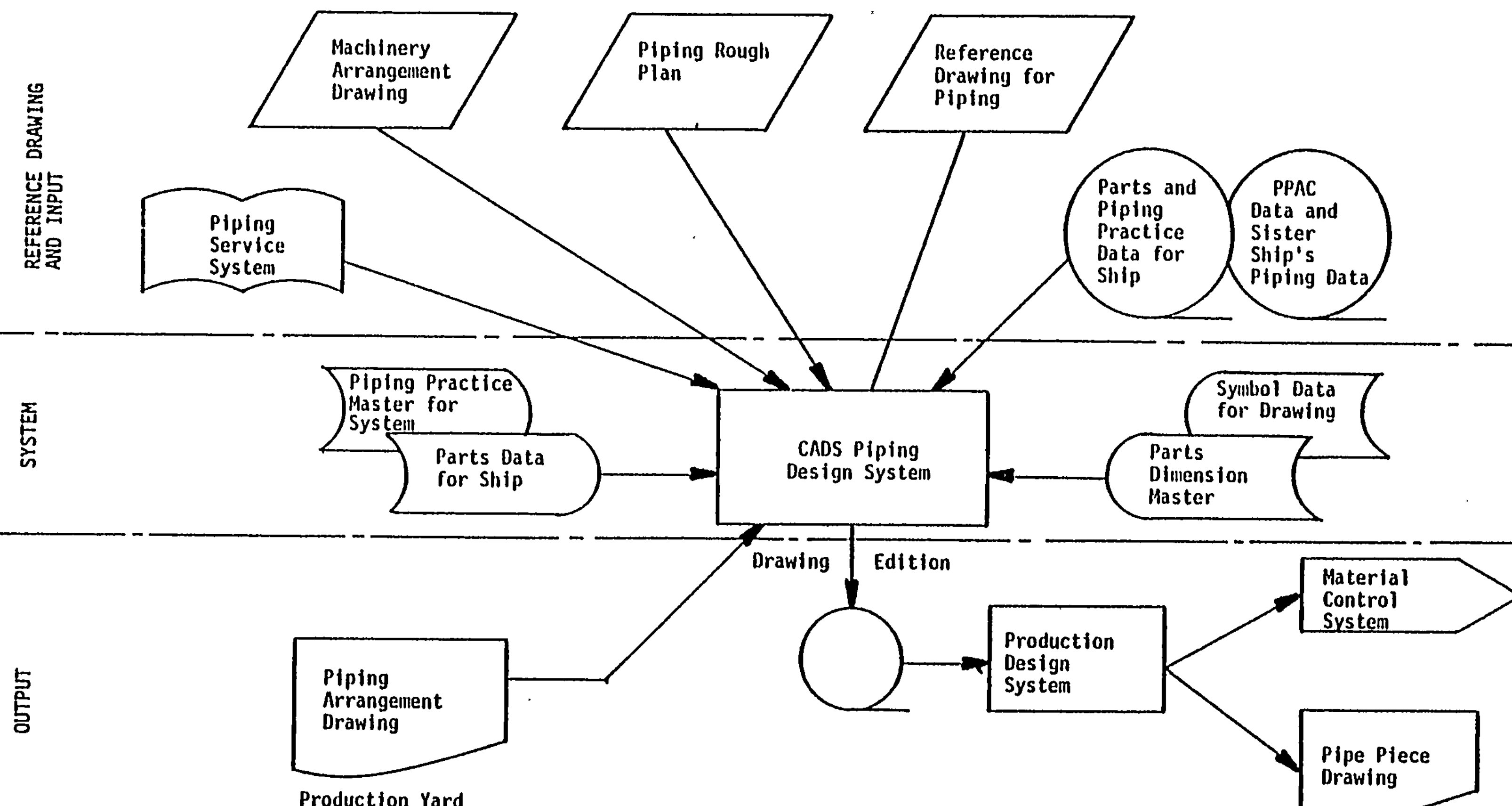


FIGURE 4-2

CADS OPERATION

This data is applied to the input through various processing routines. Simple commands are utilized to perform the various functions. Set up and locate commands start the processing and narrow the scope of application to a specific area of the vessel as well as specific parts of the piping system. The draw command enables the designer to automatically draw parts of a hull, unit, line or piping support (or all). There are also commands for clearance checking and piece checking as well as a variety of commands for making modifications, additions or deletions to drawings.

Output of the system yields the piping arrangement drawings to be used for production by the yard. Information for the material control system and for the manufacturing of the pipe pieces is also a part of the output of the CADS system.

Figure 4-3 describes the process flow of piping design from basic design and functional design through drawing preparation for engineering and production. The contract specifications for all piping systems which may include schematic diagrams and the general arrangement are transferred from the Head Office to the shipyard design department where the functional design will be firmed up as a master piping diagram, machinery arrangement and the pipe passage layout which shows available space for piping.

The general information that makes up the functional design is the basis for the final design of all piping systems on the vessel. From this information all items that have not been purchased are written on purchase orders for orderly procurement. It should be noted that the basic material list which is also given to the shipyard design department as part of the basic design package is updated as the

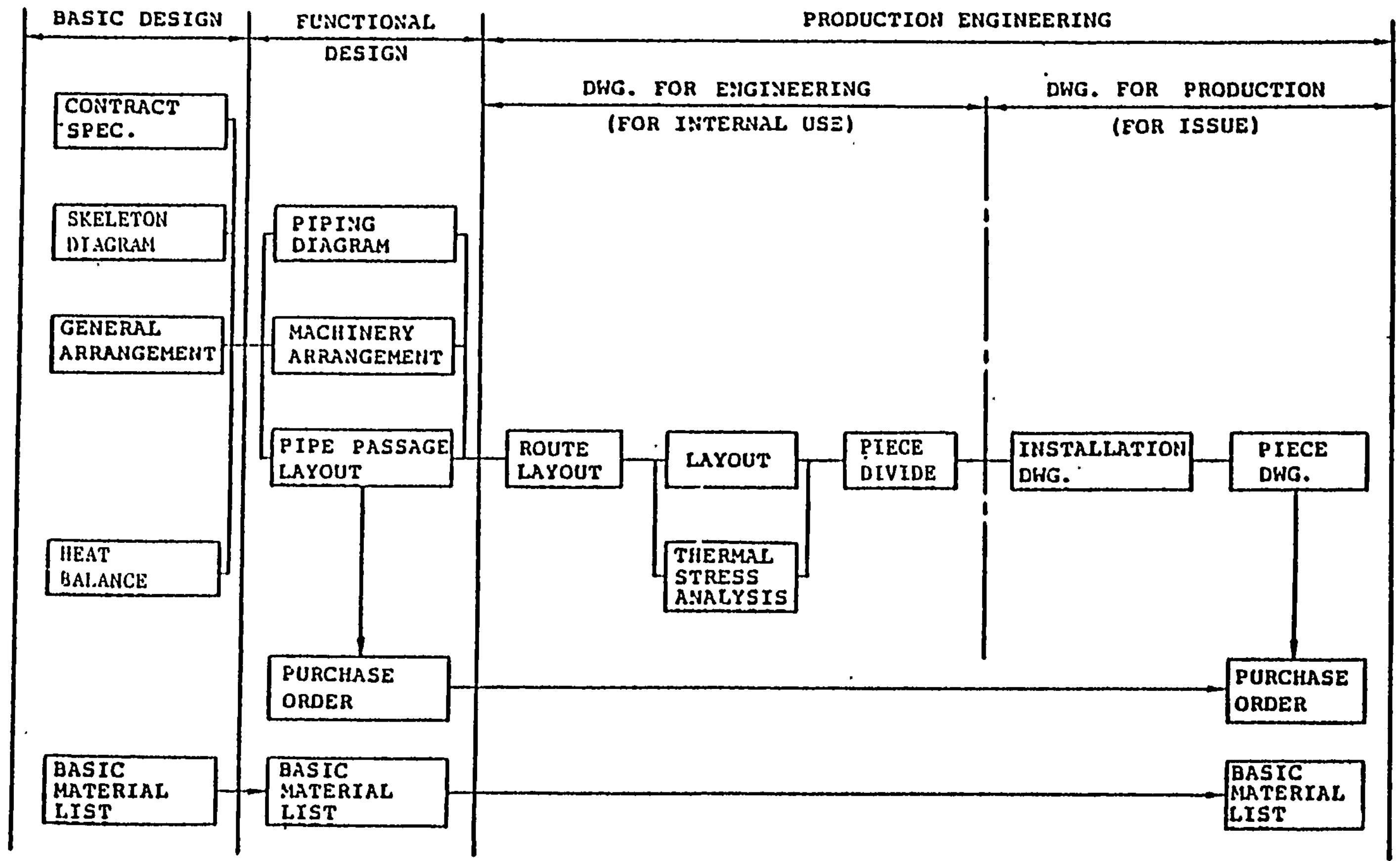


FIGURE 4-3

PROCESS OF PIPING DESIGN

functional design progresses. This feedback of data to the material list is an important part of the design process from the beginning to end.

Drawings for internal use in the design of the vessel's piping include basic routine layouts and more refined system and module layouts. After thermal stress analysis is made on each piping run, the actual pipe piece divisions are the basis for the working drawings that will eventually be issued for production.

The drawings for production will include installation drawings which are detailed assembly and installation instructions and pipe piece drawings which will be used in the manufacture of all pipe for a particular piping run. As the pipe piece drawings are completed, the purchase orders for any unordered material are written and once again the basic material list is updated.

Figure 4-4 illustrates the relationship of the CADS system in the preparation of detail piping design. As the transition from functional design to detail design is made, utilization of the CADS system begins. Both manually and automatically prepared data are processed by CADS. The CADS system is labeled as Interactive Design because it actually interacts with the manual and automated inputs to produce installation drawings, as well as simultaneously updating the design information file. The design file is an integral source of data for producing the pipe piece drawings and the material lists for pipe.

Outputs of the CADS system utilize hull structure drawings to identify obstacles and interferences for piping. Main hull structures such as frames, longitudinals and decks are registered and drawn by the system. Three part drawings of piping plans show plan, side and

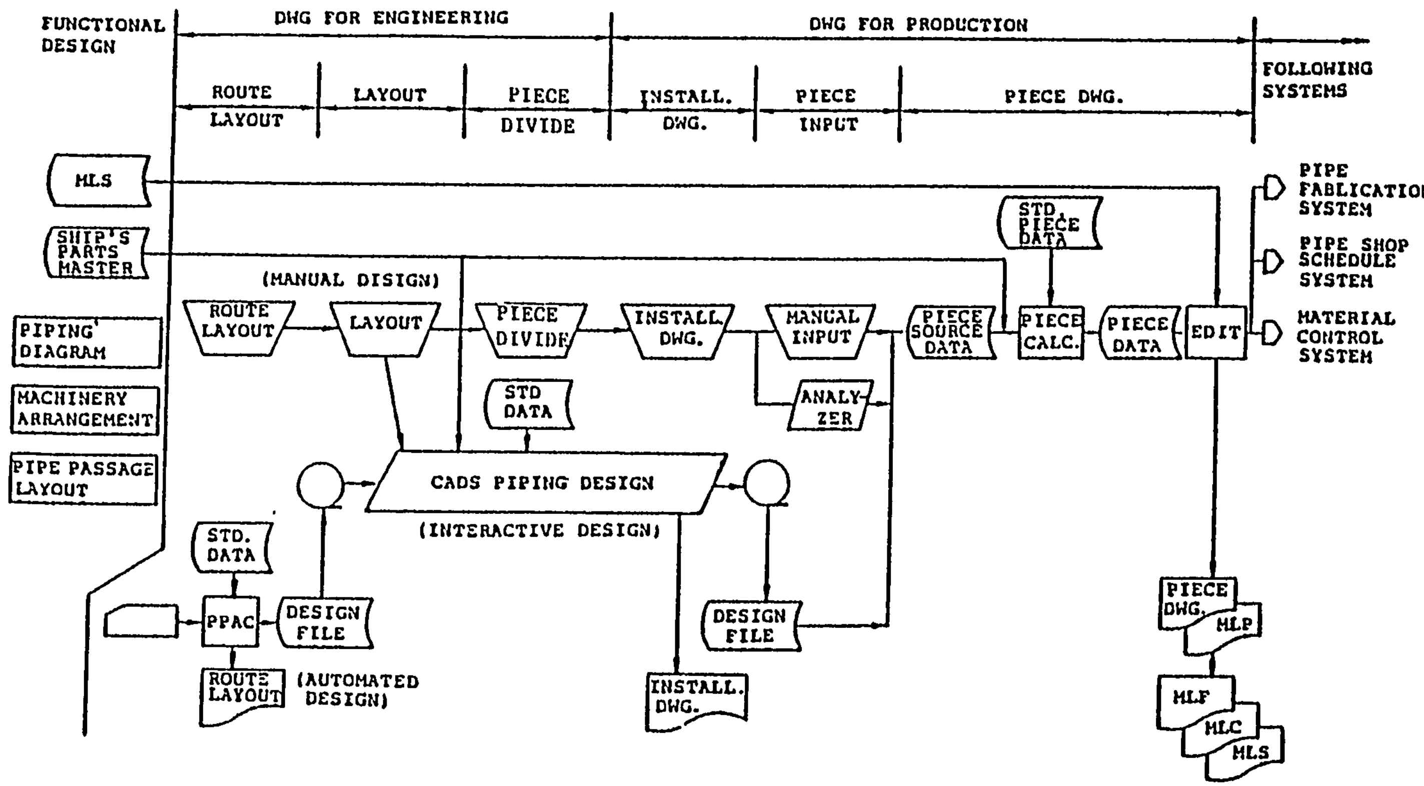


FIGURE 4-4

PIPING PRODUCTION ENGINEERING SYSTEM (ENG. RM)

section views. Definitions of piping runs is accomplished by indicating start and end points and bend points. Optional section drawings are available as outputs to show intersections of pipe with other structures such as tanks and bulkheads. Clearance between pipes is calculated automatically.

Other functions and characteristics of the CADS system are the setting of pipe fittings on a piping run, checking pipe piece dimensions based on fabrication standards, design of pipe support pieces, and providing data for the pipe piece fabrication system and the material control system.

SECTION 5

NUMERICAL CONTROL STEEL FABRICATION

5.1 GENERAL

The design work for the hull involves the preparation of a rough structural drawing and a shell plate expansion drawing based on a typical midship section plan and a lines plan for a given vessel. Following this, detailed structural calculations are conducted and a detailed structural drawing is prepared. During these design processes, the data base is continually added to and updated. The result of this building up of the data base is a structural drawing produced by computer directed automatic drafting machines, plotters or other graphic displays.

The preparation of structural drawings by computer points out the fact that the shapes of the various pieces are dealt with numerically. As part of the data base, these numerical data are directly tied in with the N/C (numerical control) marking and cutting equipment. The main result of this is omission of traditional mold loft practices with more automation of the production system.

At IHI, automation of many fabrication processes has led to more accurate and rapid fabrication of steel parts as well as creating more simplified jobs for the workers. Automated production can also be a deciding factor in solving the skilled manpower shortage problem found in the U.S. shipbuilding industry.

5.2 GAS CUTTING AT IHI

The philosophy and policies which affect numerical control steel fabrication in Japan's shipyards have evolved as a result of certain

conditions prevalent in the Japanese shipbuilding industry. The abundance of highly skilled manpower, industry standards and highly developed facilities, among other conditions, have enabled the IHI yards to utilize N/C methods of fabrication without relying on them to perform jobs better suited to other types of equipment and methods. By contrast, some U.S. shipyards must rely on N/C marking and cutting for a major portion of the fabrication of steel ship parts due to skilled manpower shortages and a lack of alternate facilities for fabrication.

IHI shipyards tend to process by N/C methods only those ship parts requiring high precision and repetition of shapes and which can be cut using the same N/C tape. Even though N/C methods provide the capability for cutting two or three plates at one time, preparatory work such as nesting operations require a good number of manhours. For example, to nest twenty pieces into a raw plate consumes from 1.5 to 2 manhours. Thus, IHI's N/C machines are mainly utilized for fabrication of main structures such as web plates, innerbottom floors and girders, and curved shell plates.

For flat plate units such as portions of the main deck, the sequence of plate fabrication and assembly partly accounts for the fact that only 25% of the plates for a bulk carrier are produced by N/C machines. At lHI, each plate for such a flat panel unit is neatly cut by a flame planer, then welded together with the other plates of the unit. Finally marking on a unit (not single plates) is performed before putting on internal structures such as sub-assembled webs or angle stiffeners.

IHI's alternative to old methods of mold lofting is the 1/10 scaled body plan lofting method. Large table automatic drafting machines

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IHI’s alternative to old methods of mold lofting is the 1/10 scaled body plan lofting method. Large table automatic drafting machines

After a panel has been neat cut on a flame planer and welded, the steel tape is used for marking all stiffener locations. The steel tape is first laid down near the edge of one side of the panel and all locations are marked with chalk or a marking pencil. This procedure is then duplicated on the opposite edge of the panel. After the marks have been applied to both edges, a chalk line is “popped” between edge marks. It is in this manner that panel marking is accomplished using steel tapes prepared from N/C data.

For marking single plates, two main methods are applied, N/C plate marking and Electro-Photo Marking (EPM). Selection of the method of marking is made with regard to leveling the workload of the yard’s marking facilities and with consideration for smooth work flow. On a Future 32 class bulk carrier built at IHI’s Aioi shipyard, approximately 39% of the plates are marked using EPM. These plates are then cut by manual or semi-automatic burning.

The EPM method of plate marking has been in use at the IHI shipyards for more than ten years, and came about as a result of a blend of optics and electronics. EPM is a rapid method of marking that can mark a raw plate in about eight minutes. In a special dark room, the raw plate is positioned on rollers beneath a light projector that is equipped with a precision lens designed to enlarge a 1/10 scale image to full scale on the plate below.

The image that is projected is made of various 1/10 scale piece drawings produced on clear film by automatic drafting machines. These small drawings are nested on a large piece of clear film which is a 1/10 scale representation of the plate that is to be marked. All

necessary material marks are manually added to this nested drawing before it is placed in the projector so that when the EPM process is completed, all pieces will be completely marked.

Phototoner, a light sensitive powder charged with static electricity, is spread over the plate. The nested 1/10 scale drawing is then projected at full scale onto the plate. This step in the process causes the projected image to adhere to the plate. The precision of the printed pattern is accurate enough for the fabrication of hull pieces.

Numerical control plate marking is accomplished by burning zinc or plastic powder onto a plate to form a continuous 1/16" wide line. A special burning torch equipped with a hopper/dispenser applies the powder to the plate just ahead of the moving torch. This method of line marking is capable of laying down a continuous line at the rate of forty feet per minute.

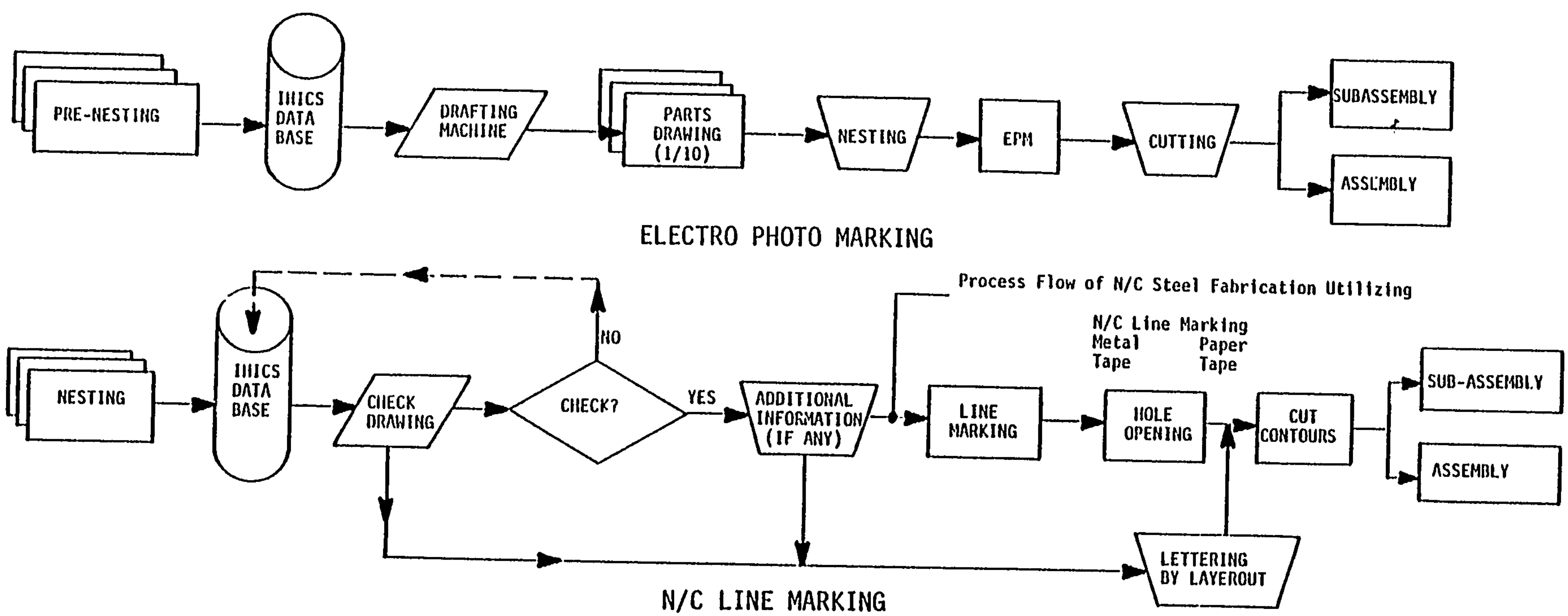

FIGURE 5-1

PROCESS FLOW OF N/C STEEL FABRICATION UTILIZING ELECTRO PHOTO MARKING AND N/C LINE MARKING

SECTION 6

LIVINGSTON SYSTEM AND APPLICATION OF IHI TECHNOLOGY

6.1 APPLICATIONS OF IHI TECHNOLOGY

During the course of the Technology Transfer Program, Levingston has studied the IHI design and engineering systems and practices. The various studies entailed detailed analysis and comparisons which in most cases led to decisions for implementation of the IHI technology or methodology with modification if necessary, or to reject it after cost trade-off studies were applied.

In some cases, implementation of IHI technology in areas of the shipyard other than design and engineering has brought about the need to change certain design and engineering practices accordingly.

6.1.1 Computer-aided Ship Design

In the area of computer-aided ship design, the IHI system and the SPADES system which is in use at Livingston were compared. Detailed documentation of both systems facilitated this comparison.

It was determined that both systems were relatively equal and there would be no need to change from SPADES to the IHI system. At that point the study concentrated on determining if full benefit from SPADES was being realized. All available SPADES modules were studied including those not in use at Livingston. A detailed comparison table of SPADES and the IHI system is provided in Appendix J of this report.

In conclusion to this study it was determined that both systems are very good shipbuilding tools, and while the IHI system is fully utilized to the best advantage of the IHI shipbuilding complex, SPADES

at Levingston is somewhat limited by lack of implementation and facilities. It was determined, however, that SPADES may be better suited to Livingston's purposes and methods. For example, those SPADES modules that actually duplicate the old style lofting were better for Livingston because the input coding is easier and the data base is referenced by all of the SPADES modules, whereas in the IHI system some modules are of the "stand alone" type and require additional inputs. Thus it was decided that implementation of the IHI system was not necessary and that as Levingston's requirements for computer-aid design software increased, SPADES could provide what is necessary.

6.1.2 Numerical Control Steel Fabrication

Some changes in Levingston's steel fabrication methodology changed as a result of IHI's recommendations. In the area of bending and shaping steel plates for the shaped zones of the hull the IHI methodology for cold bending followed by flame bending (or line heating) was implemented. This created new demands upon the mold loft for providing special sight line templates necessary for this process. Of course flame bending is only one step in the overall method of curved unit assembly used extensively at IHI. When this method of assembling large curved units on adjustable pin jigs was adopted still more demands were placed on the loft. In these cases, the SPADES system already provided enough data for preparing the necessary templates and for setting the heights of the pins of the adjustable jigs. It was only a matter of utilizing what was available.

In other areas of numerical control steel fabrication some deficiencies at Levingston were identified after comparison to the IHI methods and facilities. Because of various conditions present

at Levingston, and also conrnon to other U.S. shipyards, almost all lofting work was performed in the N/C loft and almost all plate was marked and burned by the N/C burning and marking machine. As an alternative to this practice of burning everything by N/C methods, another method of automatic burning has been installed in the form of a 1:1 optical-tracer burner director. This has lessened the load on the N/C burner considerably. A high speed parallel burner has also been installed for burning flat, straight plates.

Various other recommendations from IHI have also been implemented such as leveling of the workloads between the various processes for fabrication and rearrangement of shops and facilities.

6.2 FUTURE APPLICATIONS OF IHI TECHNOLOGY

Many recommendations have been received from IHI as a resul tof the Technology Transfer Program in the area of engineering and design. One specific suggestion involves the installation of a large table automatic drafting machine in the mold loft and a drum type plotter/ drafter in the design department.

IHI uses the large drafting machine for making templates for cutting and shaping and for verification of parts. The high accuracy and speed of the machine makes it possible to use its graphic output for directing optical tracer type burning equipment as well.

In the design department, the drum plotter calls upon the established data base for a ship and rapidly produces drawings that can be sectioned and detailed and actually used for working drawings.

Addition of both of these machines could result in significant manpower saving both in the mold loft and in the drafting sections of the design department.

In general, the design department has the following major functions to perform:

1. Preparation of technical information for new ships: including Basic Material List, Purchase Order Specifications for long lead time items.

2. Basic Drawings (Gen. Arrg't) and Key Plans & Maintenance of Basic Material List & Purchase Order Specs.

3. Working Drawings: Hull Structural Details, Outfit Composite Drawings, Manufacturing Drawings (Pipe Fabrication), etc.

4. Testing Plan and Procedures

5. Finished Drawings and Operational Manuals

6. Accumulation of Technical Data, Maintenance and Improvement of Standards

Because of specific conditions that affect the organization of medium sized U.S. shipyards, IHI realizes that recommendations for changes must be tailor-made. For example, a shortage of skilled manpower in the design department gives rise to consideration of the following:

1. Utilization of subcontractors for design, computerized calculations, and material procurement data.

2. Concentration of LSCO. manpower on:
   *Engineering of total system (Material & Performance)
   *Working Drawings with all information necessary for production (aid to Productivity & Manpower Economy)

3. Timely issue of working drawings in advance of Fabrication Start and the quality of information on the working drawings will greatly influence total production manhours.

Thus, through the utilization of subcontractors for some portions of design engineering, limited manpower can be saved and effectively directed toward engineering the ship as a whole and checking (and making alterations when required), the drawings and data received from the subcontractor.

Some benefits of this recommended policy may be as follows:

1. Ability to obtain accurate ship's cost based on ship's specifications and accurate basic material list
2. Better situation for Purchasing
3. Timely receipt of vendor drawings and actual material
4. Short time period for issue of working drawings

6.2.1 Zone Outfitting and Composite Drawings

The IHI methodology for outfitting a vessel involves Zone Outfitting and Palletization. These concepts provide benefits to the total system in terms of manhour savings, material management and personnel attitudes. However, more engineering time is required to support them.

Zone outfitting and the pre-outfitting of hull units prior to erection may do more than any other single aspect of IHI technology toward optimizing timely and profitable ship production. Therefore, whatever design and engineering methods, systems and practices are required for their implementation must be carefully considered.

Transformation to zone orientation begins with a hull unit arrangement or breakdown. The next step is preparation of composite drawings for outfitting according to the established three dimensional outfitting zones. These components show zone boundaries and include all systems within that zone. Interferences between systems are recognized and eliminated during the preparation of these composite drawings.

6.2.2 Work Instruction Drawings and Material Lists

Further processing of the design is necessary for producing the working drawings to be used by Production. These drawings identify the area of the outfitting zone and the stage of the production sequence at which the work will be performed. For the hull, designations are made on assembly, sub-assembly and cutting plans. For

outfitting, designations are made on work instruction drawings, each of which is developed with its own material lists for the on-board, on-unit or sub-assembly stages. This hierarchical sub-division continues by zone/area/stage with the preparation of the detail design drawings for pipe pieces and components other than pipe and their respective material lists.

It is in this manner that the engineering and planning process continues until each zone is broken down to a minimum level. The material lists also facilitate palletization, the IHI method of material management. The material lists for a specific zone/area/stage are used to gather the material and place the material in a physical pallet for shipment to the site at which that material will be installed. Such an organized material system facilitates rapid performance of outfitting tasks, whether they take place at the sub-assembly, on-unit or on-board stage.

6.2.3 Automated Scaled Body Plan of Mold Lofting

From the early stages of the Technology Transfer Program, IHI has recommended implementation of scaled body plan lofting. This system involves the installation of a large table automatic drafting machine in the mold loft and a drum type plotter/drafter in the hull section of the engineering department.

IHI uses the large drafting machine for making templates for the cutting, shaping and verification of parts. The high accuracy and speed of the machine makes it possible to use its graphic output for directing optical tracer type burning equipment and for high efficiency electro photo marking equipment.

In the engineering department, the drum plotter calls upon the established data base for a ship and rapidly produces drawings that can then be manually sectioned and detailed and actually used as working drawings.

The addition of both of these machines could result in significant manpower savings in the mold loft and the engineering department's drafting sections.

6.2.4 Additional Future Implementation

In addition to those specific areas of future implementation identified in the preceding paragraphs, other methods, systems and practices may become necessary at Livingston. As the production methodologies evolve and change, so must the practices of those functions that support this production. Design and engineering must provide what the total system requires and at the same time must be provided with the support and lead-time necessary to successfully perform those functions.